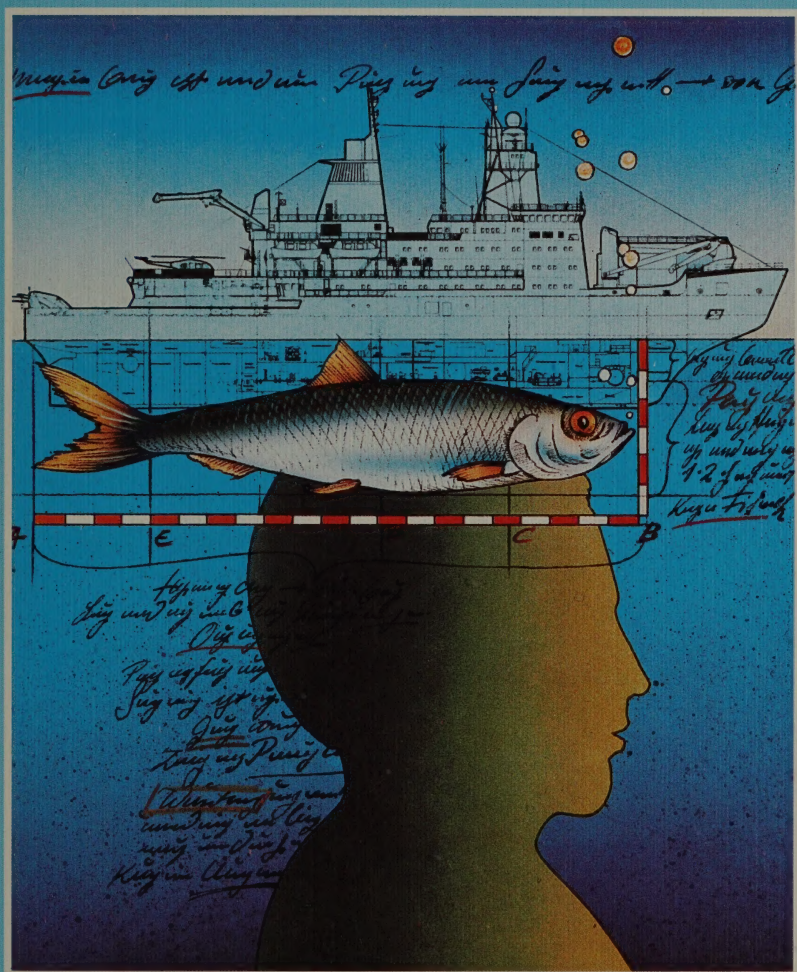


Marine Research

Programme of the German Federal Government



Federal Ministry of Education, Science, Research and Technology



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Foreword

In the past, not only natural events but also human activities affecting the environment have caused significant and tangible changes in the living conditions on Earth. However, it has only been in the past 20 or 30 years that man-made environmental damage – to a large extent resulting from uncontrolled population growth – has reached such dimensions that this damage jeopardises both our living conditions and those of future generations, mainly because of its global scope.

Not only do these changes have an adverse impact on the general quality of life, but in the long run they also pose a potential threat to the global societal and economic system. For this reason, measures have been adopted worldwide to protect the environment. The United Nations Conference on Environment and Development (UNCED), held in 1992 in Rio de Janeiro, was clear evidence of the fact that this process has been initiated.

Many of the processes and interactions which underlie the global changes are known to a limited extent only, or not at all. However, effective damage prevention and risk containment strategies can only be developed by politicians if they have reliable basic information at their disposal. This is a challenge, therefore, that confronts politicians and scientists alike. For this reason, the German Federal Government has considerably increased its spending on environmental research in the past ten years.

The present "Marine Research" programme is part of a new environmental research strategy in the framework of which research is carried out to devise a concept for sustainable development. In the next few years, we will have to start by closing the current gaps in our basic understanding of the marine ecosystem and the interdependencies between the oceans and the climate. However, it will also be important to develop concrete solutions for environmental problems once they have been identified, and to draw up concepts for environmentally sound ways of producing and using natural resources. The preconditions in Germany for mastering these challenges are good in terms of human resources and existing institutions, especially since German unification, which has added valuable potential. Cooperation with interesting and important partners in the countries of the former Eastern bloc has substantially broadened the scope of our research. This will have a positive impact with regard to our overall understanding of the environmental and climate issues.

In view of the scope and the complexity of the challenges ahead of us, there is a need for global coordination of research. Global problems can only be effectively tackled in the framework of a broadly-based international effort, which is also part of our strategy. Our research efforts at national level which will be designed with this in mind will be focused on specific priority areas. This is indispensable, not

least in view of the fact that there will be less financial room for manoeuvre in future. International cooperation has had a particularly long tradition in the field of marine research. We will continue this tradition and, where possible and reasonable, we will make it the rule, rather than the exception. This applies not only to global marine research and monitoring programmes such as the World Ocean Circulation Experiment (WOCE), the Ocean Drilling Programme (ODP) and the planned Global Ocean Observing System (GOOS). Instead, we also intend to step up regional cooperation, in particular within Europe. Our attention will be focused in this context on studying the Baltic Sea which, after the political opening of Eastern Europe, is now fully accessible for international research.

The implementation of this programme can thus also be seen as Germany's contribution to the implementation of the intention expressed in the joint declaration of Rio to ensure that the future will be worth living for.

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I. Introduction and Summary

70 percent of the Earth's surface is covered by oceans which contain 98 percent of the Earth's total free water volume. There are still major gaps in our knowledge about this ecosystem, which is the largest of all. Even today, many parts of the ocean are still "white spots" on our knowledge map, although the oceans – along with the atmosphere – play a **key role** in the Earth's climate and balance of resources. In addition, they are a tremendous source of mineral and living resources.

While near-shore marine regions account for only about 10 percent of the total ocean surface area, they are our most important food reservoir: 99 percent of the fish caught worldwide comes from these coastal waters. In addition, near-shore marine regions are also important habitats and recreational areas: 70 percent of the world's population live in coastal regions. The oceans and their shore-lines are affected by a wide variety of natural and anthropogenic factors, which often exposes them to latent or acute threats.

Climate changes, which are potentially caused by the man-made greenhouse effect, can also provoke changes in the ocean's regulation system (e.g. absorption, storage and release of climatically active gases as well as heat; repercussions of chemico-biological processes on the climate). Global climate change can have a direct impact on the sea level, and hence, on the shore-lines and the adjacent sea. **However:** The role of the ocean in the climate system is not yet fully understood. It is uncertain what effects climate change will have on the ocean and what changes in the oceanic system will affect the climate. Furthermore, it is not possible to this day to qualify and quantify the mechanisms of carbon transport and storage in the atmosphere, the ocean and the ocean floor, and of carbon exchange between these compartments, with such accuracy that these data could be used as a basis for making reliable predictions of future CO₂ concentrations and their effects.

In some areas, the condition of the **ecosystem "ocean"** is alarming. While the open sea still seems to be relatively "unaffected", the coastal regions and the adjacent sea are already considerably polluted by atmospheric depositions and direct discharges or inflows from rivers. In addition, submarine waste disposal sites (e.g. chemical warfare ammunition, radioactive waste) are a source of latent and even acute risks. **However:** To this day, there are no adequate means to describe the transport channels, the risks and hence the effects of creeping pollution. Furthermore, there are only limited possibilities for distinguishing between man-made effects on the marine environment on the one hand, and natural factors and changes on the other.

Although the **use of marine resources** has so far been limited to very few products, it still involves considerable risks, in some cases producing adverse effects

on the marine environment (e.g. overfishing, oil spills). A more intensive use of marine resources (which is anticipated) may lead to more adverse effects on the environment, unless the risks are assessed beforehand and new environmentally sound methods are developed. **However:** To this day, it has not been possible because of the complex interdependencies involved to make reliable predictions about the effects of extracting and using additional marine resources.

Understanding the chemical, physical, geological and biological processes in the ocean, as well as their **interactions**, is a **prerequisite to assessing the effects of perturbations** in these systems. The **ability to assess** these effects and the possibility of **developing countermeasures** can become a **vital necessity** for large segments of the world population. Because of this interdependency, marine research must not be limited to basic research. Instead, it must include impact analyses and recommendations for action. Hence, it is also an integral part of governmental precautionary measures. In view of their global dimensions, as well as their scientific complexity and their financial scope, the problems that we are confronted with today can only be solved by means of joint international efforts, to which Germany will make an adequate contribution. The activities envisaged in the framework of the German Federal Government's marine research programme will be financed by public funds made available by the German parliament.

Against this background, marine research can also be seen as **research into preventive measures** in the broadest sense. The government must assume responsibility in this particular area, too: if, on the one hand, the government promotes the development and introduction of new technologies in fields such as energy production and transport, it must on the other hand also keep an eye on the effects which these technologies have on human beings and on the environment. The changes which have occurred in the oceans – particularly in near-shore regions – are clear evidence of such effects. For this reason, marine research is closely linked with **technology impact research** and **technology assessment (TA)**. This is true not only for investigations into basic issues (e.g. the role of the ocean as a sink or source) but also for applied problems (e.g. the role of the ocean as a "waste sink").

Research Policy Objectives

The German Federal Government's current "Marine Research" programme is based on the results of preceding programmes, and its objectives are directly linked to current programmes and research concepts on environmental research and environmental technology (1989-94) and on "Global Environmental Changes" (1992-95). They are also closely linked to the German Federal Government's polar research programme which is currently being drawn up.

The marine research programme has included suggestions that have come from the political arena, and it has taken into account research needs which have been identified as being important and necessary and which are a result of the accession of the Federal Republic of Germany to a number of international agreements.

The priority topics for the programme have been chosen with the following three overriding subjects in mind:

The Role of the Ocean as a Climate Factor
The Role of the Ocean as an Ecosystem
The Role of the Ocean as a Source of Resources

The programme is aimed at the following general objectives:

1. to create the **prerequisites for better understanding the role of the ocean as a climate factor** and the **repercussions of climate change** on the ocean as a basis for future preventive and protective measures;
2. to identify adverse **natural and anthropogenic factors** affecting the sea adjacent to shores, as well as the coastal regions and the open sea; to study their dynamics and their effects; and to develop the fundamentals, as well as methods and concepts for **describing and assessing the current status**, for **predicting changes** and/or for **eliminating such adverse effects**;
3. to develop **methods and processes** for **studying and monitoring** the ocean's climate and environment, and for making **environmentally sound use** of its animate and inanimate resources.

These overriding objectives, which cover both basic and applied research activities, overlap in some areas.

The findings obtained in marine research should also serve as a basis for preparing, scientifically justifying and constantly reviewing political decisions and actions. In this context, the following results should be achieved:

- The effects of climate change should be described, and preventive actions should be recommended.
- Natural and non-natural environmental changes should be identified as problems (research into causes) and, where necessary, concrete proposals should be made for remedying the situation.
- On this basis, models should be developed for predicting climate and environmental changes.

- This should help to establish the foundations for adopting legal provisions.
- And finally, this should help to create the prerequisites for an environmentally sound development, an economically viable use and the preservation of marine resources.

Programme Structure and Priorities

The programme has been designed to meet these scientific and political challenges. It is essentially subdivided into two major sections:

First of all, **Section II. The Status Quo** describes the major framework conditions at national and international level which are relevant to the marine research programme. The two chapters on the "**Current status of research findings**" and "**Unresolved questions and research needs**" primarily deal with basic research projects, which are a prerequisite to the solution of practical problems. For the sake of clarity, the current status, as well as the research needs and the funding available for research in problem-oriented fields are described in Section III.

Section II winds up with descriptions of the **institutional setting** in Germany, the promotion of marine sciences by the DFG and international cooperation by means of bilateral and multilateral activities, as well as an outline of recent trends in the law of the sea.

Section III describes the **German Federal Government's actual programme**, which is based on the research policy objectives mentioned above. In its structure, the present programme – unlike earlier programmes – is not geared towards the research requirements of specific marine disciplines. Instead, it is oriented towards **interdisciplinary approaches aimed at finding solutions to the practical problems mentioned above**.

This Section begins by justifying the need for governmental promotion of marine sciences and describing the promotion instruments available.

The chapter entitled "**Measures**" is subdivided into two parts. The first part (**Structural Measures**) describes some general structural objectives which can be derived from the German Federal Government's particular responsibilities.

The second part (**Scientific Programme**) describes the scientific priority areas which the German Federal Government intends to promote. The approach adopted in this programme towards the promotion of basic research is also interdisciplinary in nature; the purpose of this research is to close any remaining gaps in the knowledge required to implement problem-oriented and application-oriented approaches such as those described in chapter 3.2.2. This means that basic research is expected not only to shed light on the two systems "climate" and "environment" (systems research), but also to open up new possibilities for using

marine resources. On this basis, it will then be possible to develop problem-oriented ("impact research") or applied research approaches.

The **development of technology** for these problem areas and for basic research forms the link which connects all these areas.

The scientific part of the programme does not define the various research tasks in detail; instead, it provides a more general description of the scope of funding after having outlined a given problem and having explained the research needs. This helps to make the programme **more flexible** over its relatively long period of implementation, thus enabling researchers to adapt to new developments as new findings are made. Nevertheless, it is intended within the scope of the programme to develop **promotion concepts for specific priority topics** which will be dealt with by means of multidisciplinary **master projects**. Examples of such master projects will be mentioned in the context of the various fields discussed.

The primary responsibility for the implementation of this programme rests with the Federal Ministry of Education, Science, Research and Technology (BMBT – Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie). Programme priorities which fall into the fields of responsibility of other ministries (e.g. fishery research: Federal Ministry of Agriculture; research into mineral resources: Federal Ministry of Economics; hydroacoustics: Federal Ministry of Defence; use of modes of transport: Federal Ministry of Transport) are marked as such.

II. The Status Quo

II.1 The Current Status of Research Findings

Basic marine research is supported by a variety of different disciplines which help to broaden our knowledge about the processes occurring in the ocean. Basic marine research is the platform for more advanced problem-oriented research approaches.

A general account of the progress achieved by German marine research in recent years is given below. Some concrete examples of marine research projects promoted by the German Federal Government in the past complete this chapter.

In recent years, the **geosciences** have evolved from a descriptive branch of science to a modern discipline of natural sciences using its own quantitative methods and highly developed technology. This has to a large extent been due to the impetus from geoscientific marine research. The studies conducted in this field have been the basis for the development of the concept of plate tectonics, which has made the dynamics and the history of our Earth understandable in the first place. German working groups have made major contributions in many sub-fields of geoscientific marine research, including the origin and the development of the oceanic crust, the reconstruction of the palaeocirculation of the ocean and of the palaeoclimate, the evaluation of the ocean floor as a source of raw materials, and the role played by sediments in the deposition of pollutants.

In the recent past, studies along the active plate margins and on the problem of environmental protection in the deep sea have been of particular interest. The construction and the global use of the modern research vessels METEOR, POLARSTERN and SONNE, and of a number of smaller vessels, have been a prerequisite for reaching the level of knowledge and the scientific possibilities achieved in Germany today.

Project Example: Arctic Sea Ice

The project on arctic sea ice and the associated transport processes was carried out by the GEOMAR Research Centre for Marine Geosciences, Kiel, and the Geosciences Department of the University of Bremen. The purpose of this project was to study the potential effects of global climate variability on the sea ice cover, as well as the sedimentation in the Arctic Ocean and the adjacent European Arctic Ocean.

A polynya which is several thousands of kilometers long and up to 15 kilometers wide develops during the arctic winter on the ice-covered eastern Siberian shelf in the Laptev Sea. This ice-free transition from the stationary shore ice belt to pack ice at the beginning of the transpolar drift is one of the largest "ice factories" in the world. The ice which is formed by this factory floats with the transpolar drift across the central Arctic Ocean and the Fram Strait to the European Arctic Ocean. When this ice forms, large quantities of shallow-water sediments are congealed in the pack ice; up to 50 percent of the ice cover can be covered by sediments. Below a full ice cover, only very minor amounts of sediments "precipitate" down to the sea bed. Peak flow rates were observed at the ice edge where the ice is in contact with the warm Norwegian current. The ice-bound sediments do not only control sedimentation in the Arctic Ocean and in the Fram Strait but they also play a key role for the reflection of incident sunlight (and hence, for the development of our climate).

In the Laptev Sea polynya, the formation of ice and the inclusion of sediments in the arctic pack ice is largely controlled by local weather conditions and the sea level. Drastic climate change (e.g. the drop in sea level by about 120 meters during the last Ice Age) can therefore have a substantial impact on ice formation, ice drift and sedimentation in the Arctic Ocean and in the adjacent European Arctic Ocean.

Scientific research projects were focused on studies of the continental margin and adjacent seas with a view to examining mineral raw materials, the identification of the sediment composition and the sedimentary cover in the North Sea and the Baltic Sea, as well as basic studies on palaeo-oceanography and sedimentation processes in the ocean and in the adjacent seas.

Project Example: Dipping Reflectors

This project, which was carried out by the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR – Federal Institute for Geosciences and Raw Materials), was entitled "Analysis and Synthesis of Geophysical and Geological Data from the Atlantic Ocean as a Contribution towards Global Change". This project has considerably improved our understanding of the geological development of today's oceans, and it has identified new aspects of global change. Since the 1970s, geophysical measuring methods (in particular seismics) have been applied – mainly by the BGR – in order to detect rock formations of 50 to 100 km in width and several thousand meters in thickness buried at various passive continental margins. These rock formations are characterised by a conspicuous, diverging bedding, which is inclined oceanward (dipping reflectors). Drilling operations which were carried out in the framework of the Ocean Drilling Programme (ODP) have confirmed the hypothesis that these rock formations are voluminous volcanic structures which developed when the oceanic basins developed in the course of various geological phases. The BGR's studies on the structure of the oceanic crust have shown that, during these phases, there was so much magmatic-volcanic activity even at certain mid-oceanic spreading ridges that gigantic volcanic islands were built up. The results suggest that there was a regional and perhaps global magmatic/volcanic tectonic episodicity, both at the continental rift zones and at the mid-oceanic spreading ridges. Such episodes are associated with higher inputs of gases, trace gases and dust particles to the atmosphere and the oceans, and affect the environment, the climate and the living organisms.

In addition, marine geoscientists have participated very successfully in numerous international projects. The Ocean Drilling Programme (ODP) is an example of international cooperation. Membership in the ODP made it possible to establish a research priority on palaeo-oceanography. In addition to the long-term variability of the oceans which had been studied in the past, the new perspectives of palaeoclimatic research have focused attention on short-term temporal climate variations. The technical potential of "Hydraulic Piston Coring" has made it possible to obtain a full series of undisturbed samples of deep sea sediments from a limited number of sites. These samples represent an archive of the long-term and short-term variability of the global environment.

Intensive studies conducted during the last decade in the field of polar research have considerably helped to improve our understanding of the geological history of the southern ocean and the arctic sea. Groups of German researchers have produced new and internationally acclaimed findings on the geological structure and the geological development of the Antarctic sea regions (Ross Sea and Weddell Sea) and the Arctic sea regions (Greenland Basin, Boreas Sea, Fram Strait), and they contributed new major findings about the development of the Glacial climate in the southern and the northern hemispheres.

In recent years, the standard of marine geosciences has improved so much at several locations in Germany that today there are competent groups of researchers at a number of institutes who are able to tackle the tasks to be resolved. Most of these working groups are involved in basic research on marine geosciences.

Physical oceanography and maritime meteorology have mainly dealt with impulse, energy and material fluxes in the ocean/atmosphere system, including – in some cases – the cryosphere and the geosphere. These studies are closely related to climate and environmental research. Field measurements, remote sensing and model calculations have become more and more integrated in terms of methodology.

Project Example: Vertical Convection in the Greenland Sea

"Convection in the Greenland Sea" was the title of a project carried out by the IfM Kiel and the IfM Hamburg, which was the first project in which acoustic Doppler current profiles (ADCPs) were used for directly measuring the vertical movements associated with hibernal convection and deep-water formation in the central Greenland Sea. This has helped to achieve considerable progress in the analysis and our understanding of the physical processes which occur in the presence of deep hibernal convection.

The data obtained from a mooring anchored in the central part of the Greenland Sea in order to record changes in stratification and vertical movements demonstrate the considerable year-to-year variability of the convection processes and their intensity.

Regionally, the monitoring campaigns were focused on the Atlantic Ocean and the adjacent subpolar and polar areas. In addition, they covered the Indian Ocean and the Mediterranean Sea, and they included overall surveys of environmentally relevant parameters in the North Sea and the Baltic Sea, as well as in their coastal waters. The data records obtained have considerably broadened our knowledge of the circulation, the thermodynamics and the transport of substances, as well as their variability, in these waters.

One field which has gained considerable importance is satellite altimetry, which is a synoptic method used to monitor changes in ocean epicurrents over long distances.

The model calculations largely covered the same marine regions; in addition, however, calculations were also carried out for the entire global ocean, simulating the general circulation on a climatological scale (time periods of between weeks and millenia), as well as the tides and the waves (time periods ranging between hours and months). These simulations demonstrated interdependencies between ocean circulation and astronomic or geodynamic parameters (Earth rotation, gravity field). Coupled models dealt with tropical circulation and the ENSO phenomenon (ocean/atmosphere), as well as the dynamics of the circumpolar current (ocean/ice).

More specifically, these studies provided insights into the meridional heat flow, deep-water formation and ocean ventilation, as well as interactions between the polar seas and the major oceans, and the role of the mesoscale vortex in the global energy balance of the ocean. The studies are embedded in the large-scale programmes called WOCE, TOGA and JGOFS, which will be supplemented in future by the GEWEX programme.

Project Example: Vema Channel

Two METEOR expeditions (1991-92) were carried out as part of a project conducted by the IfM Kiel. The purpose of these expeditions was to use anchored current meters in order to monitor the water exchange between the Argentine Basin and the Brazilian Basin over a period of two years in the framework of the WOCE programme. The exchange of soil water between these two South Atlantic basins is hampered by the Rio Grande ridge. However, there are two incisions in this rise: the Vema Channel and the Hunter Channel. Preliminary results have shown that the average current velocity at a level of 250 meters above the bottom of the Vema Channel is 36 cm s^{-1} , which is extremely fast for the deep sea. During one of the expeditions, the exact dimensions of the Vema Channel were measured by means of the HYDROSWEET multi-beam echo sounder system. This showed that the channel is 600 meters in depth and only 12 kilometers in width, and that there are terraces of about 4,000 meters in depth on either side of the channel.

Shelf sea and coastal research has reached a point where it is possible to run tide and storm tide models under operational conditions. Matter transfer and primary biological production are increasingly included in such models as a first step

towards developing a complex model of the marine ecosystem. In this context, coupling regional and global models is an important prerequisite to being able to model and predict processes, in particular those that are relevant for the climate or to the ecosystem.

Remote sensing is becoming more and more important for marine research. The development of relevant hardware and software products has been an important precondition for the use of the European Earth Research Satellite ERS-1, which was launched on 16 July 1991. The products developed for this purpose included sensors and data processing algorithms. New processes were also developed for aircraft-based remote sensing and monitoring of dynamic material processes occurring in shallow-sea and coastal areas.

In the field of **marine chemistry**, research has permitted the introduction of improved analytical and sampling methods which have led to new insights into the distribution and the biogeochemical cycles of many component substances in various marine regions.

Project Example: ZISCH

ZISCH (Zirkulation und Schadstoffumsatz in der Nordsee – Circulation and Pollutant Cycles in the North Sea) is a joint project which was carried out under the leadership of the University of Hamburg. The purpose of this project was to study the inputs, the distribution and the sinks of pollutants in the atmosphere, in the water body and in the floor of the North Sea.

The studies have shown that the German Bay is subject to a particularly high pollution risk because it is affected not only by pollution from the rivers Elbe and Weser but also by the generally levorotatory circulation of the North Sea and by discharges from the United Kingdom, Belgium and the Netherlands. This is all the more alarming since the tidal flats with their high biological activity which are found in this specific region are particularly important for life in the North Sea. ZISCH has also demonstrated that much of the pollution inputs reach the North Sea via the atmosphere, and that the concentrations of certain substances (e.g. mercury) have reached peak levels in the central and northern parts of the North Sea. The latter phenomenon is evidence of the increasing risk for the high sea. An important finding which the ZISCH model calculations have shown more clearly than ever before is that there is a high level of variability in the pollution load of the North Sea due to weather variations which are very likely to repeat themselves in a similar fashion in a matter of weeks or years.

These findings are in the interest of both basic marine research and reliable predictions of man-made pollution loads for the adjacent and marginal seas as well as coastal regions. Particular attention was paid to process-oriented projects dealing with substance cycles in the water column and at the sediment/water and ocean surface/atmosphere boundaries. Extensive horizontal sections in the northern and southern Atlantic Ocean provided new insights into the temporal and spatial variability of concentrations of dissolved and particulate trace substances in the top ocean layer. Studies covering wide areas of the North Sea have helped to identify the distribution of numerous chemical substances and have made it possible, for the first time, to verify oceanographic models. Extensive surveys of nutrient profiles have contributed towards our understanding of mixing processes and the biological productivity of Arctic water bodies. Furthermore, studies conducted in the field of organic and ecological marine chemistry have helped to broaden our knowledge of reactions of man-made and biogenetic compounds in the top ocean layer, in shelf and coastal areas, as well as in marine organisms, including Antarctic regions.

In recent years, the interest of **marine biology research** has been focused not only on identifying regional and seasonal variations in the populations of marine organisms (in the various trophical stages) but increasingly on process-oriented studies. Laboratory experiments and field tests – designed *inter alia* to measure the oxygen consumption of individual organisms and biocenoses, and to identify biogeochemical exchange processes – were developed for application in shallow-water, shelf-sea and deep-sea areas, and have been successfully implemented.

Another research priority are projects – which are increasingly carried out in co-operation with groups from other countries – designed to study the causes of the development of masses of planktonic algae in coastal waters, in the sea ice zone and in the open ocean. In addition, efforts were stepped up to study the interactions between phytoplankton and zooplankton in various habitats, including the Antarctic and Arctic ice zones as well as tropical and subtropical waters. This research has produced completely new findings which are also relevant to the use of living resources.

Studies in particular in the North Sea and the Baltic Sea have shown that, because of its philopatry (site-attachment) and its longevity, the benthos usually reflects natural and man-made changes and trends (e.g. due to eutrophication, oxygen deficiency and pollution load) more clearly than organisms of the pelagic region. It is also for this reason that questions relating to pelagobenthic coupling have increased in importance in recent years.

Project Example: Zooplankton/Ichthyoplankton Profiler

In the framework of MAROPT – a sub-project of EUROMAR – the Max-Planck-Institut für Biochemie (Martinsried) and the IfM-Kiel developed the first operational laboratory and field-use equipment for automatic optical registration and analysis of plankton organisms. The laboratory device can be used for automatically registering, counting, measuring and qualitatively analysing highly sensitive living plankton organisms which have either been fished or grown in cultures. The devices for field use permit automatic in-situ registration of even very small distribution patterns in the plankton. An attached image processor makes it possible automatically to identify the concentration, the size structure and the taxonomic composition of the plankton. This makes it possible to reduce the labour-intensive evaluation of plankton samples to a minimum.

In this context, increasing attention has been paid to microorganisms in the ocean in recent years. Theoretical research approaches and the simultaneous development of new methods led to the discovery of a particular biocenosis among microorganisms, the "microbial loop". In this loop, particulate organic matter is built up not only by autotrophic picoplankton but additionally also by heterotrophic bacteria and nanoflagellates which use dissolved organic matter from the ocean for this purpose. The organic matter is then fed into the food network of the microplankton and mesoplankton via ciliates. While the "microbial loop" was originally discovered in the pelagic region, it has now been detected even in the polar sea ice. In the benthic region, signs of such processes have been observed for quite some time already (e.g. "gardening").

Important findings were also obtained with regard to substance flows between the surface and the deep-sea floor as well as biogeochemical turnover rates at the sea floor in time scales of between days and years.

Marine geochemistry and biogeochemistry have made major contributions to the excellent results achieved by multidisciplinary deep sea research in the recent past. There have been new findings – some of them revolutionary – in the fields of transport and conversion of substances as well as life-cycle analyses of elements on the one hand, and the modelling of short-term and long-term climate change and of marine chemical parameters on the other hand.

Project Example: Genetic Adaptation

The University of Hamburg carried out a project entitled *Genetic Adaptation to Increased Heavy Metal Concentrations by a Natural Bacteria Population in the Littoral Zone of the German Bight*. The purpose of this project was to study adaptation mechanisms of bacteria at German Bight sites with high heavy metal concentrations. For this purpose, the investigators studied the resistance to cadmium and lead of bacteria populations taken 1 meter below the water surface at two stations – one in the mouth of the river Elbe and one in the western part of the North Sea – with different concentrations of heavy metals. The resistance found to the two heavy metals mentioned above was site-specific. Resistance to cadmium was mainly observed at the station with high cadmium concentrations (estuary of the river Elbe) but not at the pelagic station where Cd concentrations were low. On the other hand, almost all the bacteria isolated at the two sites were resistant to lead, which seems to be due to the substantial aeolian lead input, which also affects the pelagic region of the North Sea.

Studies along the Galapagos Rift system – initially conducted with deep dragged probes and cameras and subsequently with deep submersibles – led to important new findings about submarine volcanism, sulfide mineralisation, extravasating superheated solutions and fluid mixtures as manifestations of the formation (active accretion) of new oceanic crust. In these areas, there are also benthic biocoenoses with enormous population densities and very large sizes of individuals.

While the geophysical and physical results had been expected, the geochemical and biological findings came as a surprise. The intensity of the geochemical transport of substances at these plate margins can best be explained by the fact that, due to hydrothermal circulation, the total volume of the ocean is exchanged once in 6 million years along the spreading ridges in the global plate-tectonic framework. The studies on this hydrothermal effect on substance cycles in a marine environment have not yet been completed.

Project Example: Hydrothermal Field

The structure of the middle Okinawa trough was studied in the framework of three research projects (SONNE expeditions 55, 56 and 71) by the Universities of Clausthal and Hamburg in cooperation with the Geological Service of Japan in order to find out whether any mineral raw materials had formed due to hydrothermal effects.

The findings of the research projects included the detection of a caldera-like basin located in the central part of a rift segment from which very hot solutions were discharged. The hydrothermal springs in the north-eastern region of the rift reach temperatures of only between 50 and 200 degrees Celsius, and they are characterised by oxidic and carbonatic-sulfatic mineralisations. However, in the central region (Izena basin) there are complex mineralisations in an active hydrothermal field ("Jade Ore Field") with temperatures of up to 320 degrees Celsius. The sulfidic mineralisations take the form of chimney-like structures of several meters in height, plate-shaped ore deposits, as well as ore impregnations and fissure fillings in altered acid volcanic rocks. Four different types of ore can be distinguished; the samples show high concentrations of zinc, lead, copper and iron, as well as up to 1.2 percent silver and up to 24 mg/kg gold. The "Jade Ore Field" is the first massive sulfide discovery worldwide in a young intracontinental backarc basin. Its mineralisations can be regarded as a recent example of fossil Kuroko-type deposits.

In the past, the deep sea had generally been characterised as a habitat for small organisms with minimum turnover rates. However, the biocenoses found at hydrothermal springs prove to be fundamentally different from other deep-sea biocenoses in terms of their structure. In particular, their energy basis is not the photoautotrophic primary production of the euphotic zone but the chemoautotrophic primary production of free bacteria living in symbioses with various animals. These bacteria obtain their energy from the oxidation of reduced substances (e.g. sulfides, methane, ammonia) which are removed from the oceanic crust by circulating water and returned to the ocean by convection.

The adaptation of the deep-sea life forms to these extreme conditions, as well as the analysis of the substance flows and the assessment of the geochemical, biogeochemical and isotopic characteristics of this unique ecosystem are the object of intensive research efforts. This also applies to the formation of sulfidic ore deposits, the distribution of trace gases (helium and methane) and the geothermal heat budget.

In addition to the detection of these chemolithotrophic ecosystems at mid-oceanic ridges, there have been other discoveries in the past few years with regard to other tectonic units. These discoveries include the discharge of fluids and gases in response to the pressure from colliding plates in subduction zones, e.g. in the circum-pacific plate structure, as well as discharges of cold water with high salt contents or high hydrocarbon and gas concentrations at faulted zones along passive and active margins. Under these specific geochemical conditions, there are also chemoautotrophically controlled biocenoses which show some similarity to those found at mid-oceanic ridges.

The origin of the food for these organisms, as well as the energy needed for the microbially controlled benthic conversion of substances in the deep sea, have been discussed for a long time. Findings from sediment traps led to new research initiatives and changes in past views about the vertical transport of substances. These findings have shown that sedimentation is a quick process since the input of organic matter is subject to seasonal and interannual impulses so that there is an unexpectedly rapid and almost complete coupling between the upper, light-perfused zone and the deep sea. Experiments which were carried out under simulated deep-sea conditions also showed high bacterial turnover rates. This means that the rate of decomposition of organic matter is much faster in the deep sea than hitherto assumed. This also considerably increases oxygen depletion and the rate of nutrient return to the ocean.

II.2 Unresolved Questions and Research Needs

Although research efforts have been stepped up worldwide in all marine disciplines and although there have been undeniable advances in many areas, there are still considerable gaps with regard to our basic understanding of the global climate and ecosystem as a whole.

The following chapter will identify these gaps in our knowledge and describe the contributions which the various disciplines can make in order to fill these gaps in the next few years.

Marine Geosciences

Based on the findings obtained to date, research programmes in the field of marine geosciences will concentrate in the next few years on the following issues: complex geological processes in the active mid-oceanic ridges; the structure and the characteristics of the oceanic crust in time and space; the structure and the geological development of shelf edges; the history of the oceanic water masses and of their biota; the geo-microbiological processes involved in sedimentation and the

development of deposits; palaeoclimatic research as a contribution towards climate predictions; sedimentation and sediment dynamics; substance cycles; and the fluid/gas exchange between the ocean floor and oceanic water masses.

One priority of new international research programmes will be to study hydrothermally active plate margins. These studies to be conducted at the mid-oceanic ridges (which are active rift zones between two lithospheric plates moving apart at a rate of between 1 and 20 cm/year) will be designed to shed light on the following issues: the flow of mantle material; the processes leading to the development of magmatic melt and its conversion to crystalline oceanic rock; hydrothermal circulation; and the geochemical cycles.

The primary issues to be studied in the active subduction zones are the temporal sequence and the structural development of the sedimentary accretionary wedges and the associated processes. The fast geodynamic changes in the active plate margins permit a large number of real-time measurements. Since many of these changes are controlled by volcano-magmatic, seismotectonic and hydrological processes, greater use should be made of the available petrological, hydrodynamic and seismotectonic know-how. Real-time measurements also require the development of innovative deep-sea sensors as well as new technologies for carrying out measurements, observations and sampling under extreme geochemical conditions, and at high temperatures and pressures.

Germany cooperated successfully in the Ocean Drilling Programme (ODP), the international deep-sea drilling project.

Ocean Drilling Programme (ODP)

The purpose of the ODP is to examine the factors underlying the complex interrelations in the ocean-atmosphere-biosphere-geosphere system. The information "frozen" in sediment deposits improves our understanding of geological and recent developments as well as of the climate and biogeochemical substance cycles. The core issues of the ODP include:

- the structure and the composition of the oceanic crust and the upper layer of the Earth's mantle,
- the dynamics, kinematics and deformation of the lithosphere,
- the fluid circulation in the lithosphere,
- the causes and effects of ocean and climate change, and
- the evolution of marine pelagic biota.

At the Second Conference on Scientific Ocean Drilling (COSOD-II), which was held in 1987, the participants defined the priorities for the Ocean Drilling Programme up to the turn of the century, based on the findings obtained up to 1987.

The drilling programme defined in the ODP long-term plan (1993-2002), which was accepted by the partner countries as a binding planning document, shows certain priorities.

Because of its past 24 years of experience, the deep-sea drilling programme is able to produce new important findings about the mode of action of the complex system called "Earth" with every drilling campaign. With the drilled material, which contains geological information going back several millions of years in the Earth's history, the ODP provides the indispensable historical background which helps us understand processes which occur today.

Since the sample base is regionally still rather limited and since drilling capacities will be tied to deep drilling targets for a longer period of time, it becomes more and more apparent that it is necessary to develop an additional sampling system suitable for a penetration depth of 300 meters. Research efforts aimed at dating marine sediments will have to be stepped up so that the marine proxy data to be obtained can be fitted into a reliable time framework (inter alia by improving physical and mass-spectrometric dating methods).

In addition, marine geosciences can make an important contribution towards predicting future coastal developments because of their research into the coastal genesis of transgressing oceans.

Research in the Fields of Marine Chemistry, Biogeochemistry and Geochemistry

We are still prevented from fully understanding the marine cycles of natural and man-made, inorganic and organic trace substances and pollutants by a lack of important information, mainly with regard to the heterogenous reactions between dissolved and particulate substances, as well as the mass flows between ocean compartments. The following points are of particular interest in this context: the vertical flow of dissolved and particulate matter in the water column; the flow of substances between sediment surfaces and deep water; and the gas exchange between the ocean surface and the atmosphere.

There are major gaps in our knowledge with regard to the identification of the chemical states of dissolved trace metals ("**speciation**") as well as the characterisation of low-molecular-weight organic substances in the ocean which can be of either biogenic or man-made origin. Shedding light on chemical structures is important not only for our understanding of the biogeochemical cycles of these compounds but also – and most importantly – for our assessment of their **impact** on the marine ecosystem. In this context, particular attention should be paid to

biologically active trace metals and to organic sulphur and halogen compounds. In addition, possible interactions between trace metals and marine metabolites are also part of the unresolved questions. There is a need for improving the methods used for quantifying dissolved high-molecular-weight organic carbon and nitrogen compounds (DOC and DON). As long as these compounds cannot be measured with sufficient accuracy and differentiation, it will be possible to make statements about such issues as the global carbon cycle to a limited extent only.

Continental shelf areas and their role in the global cycle of chemical substances are an important field of research. Of particular interest in this context are questions relating to the assessment of the function of adjacent seas, as well as the function of coastal zones as sinks for inputs of both natural terrigenous substances and man-made potential pollutants. Another question yet to be answered is what role the continental shelf areas play with regard to the absorption and formation of radiatively active trace gases.

Against the background of increasing atmospheric CO₂ concentrations and their repercussions on the global climate, the global carbon cycle is becoming increasingly important. The ocean plays a crucial role in this cycle. According to current estimates, between 30 and 50 percent of past man-made CO₂ emissions has been absorbed by the ocean, although there are no direct measurements to back up these estimates. Identifying the response of the ocean to increased CO₂ concentrations in the atmosphere requires not only computer modelling but also large-scale international long-term monitoring programmes. It will be necessary in this context to determine the parameters of the carbonate system (especially the CO₂ partial pressure in water) and the concentrations of dissolved organic carbon, in particular in deep-water source areas, as a function of the prevailing hydrographic and biological conditions. Only in this way will it be possible, in conjunction with model calculations and remote sensing techniques, to establish the CO₂ flux between the ocean and the atmosphere or to detect changes in the carbon reservoir of the ocean.

The biogeochemical cycles of a large number of trace substances are also coupled to the atmosphere or are even dominated by atmospheric fluxes. This also applies to the exposure of the adjacent seas to various pollutants. While data on atmospheric concentrations and depositions are available from coastal monitoring stations, future programmes will have to concentrate on carrying out series of measurements above the open sea. What is essential for the assessment of recent conditions is the reconstruction of long-term and short-term changes in the Earth's history. The purpose of measuring concentrations of trace substances and isotopic ratios is to draw conclusions with regard to the oxygen, nutrient, carbon dioxide and methane concentrations as well as the temperatures of a meridional ocean under glacial and interglacial climate conditions.

There are also major gaps in our knowledge of the biochemical adaptation of organisms to the extreme conditions prevailing in the deep sea, and in our knowledge of conversions of substances at the ocean floor. These questions are being studied in the framework of the JGOFS Programme.

Geochemical and biogeochemical studies are crucial for improving our knowledge of marine deposits. Corresponding findings and methods will have to be developed, refined and applied for the specific tasks involved in explaining the genesis of deposits, as well as the exploration and prospection of deposits. Non-ferrous deposits – in addition to hydrocarbon and ore deposits – play an increasingly important role in this context. The biogeochemical accumulation of substances is probably a key factor in the formation of non-ferrous deposits.

Research in the Field of Marine Biology

Marine biology is currently undergoing considerable change. Separate studies in the sub-fields of marine zoology, botany or microbiology, which were predominant in the past, are increasingly being replaced by research efforts which integrate all these various sub-fields. The primary objective of such research is to analyse the structure and functioning of marine ecosystems, and thus, to quantify the life processes in the ocean. Since ecosystem analyses invariably require research into the interactions between abiotic and biotic components, marine biology has to co-operate closely with the other scientific disciplines involved in marine research.

Basic research and problem-oriented research are closely linked with one another in analyses of ecosystems. Basic research studies the life strategies of the various species on the basis of their genetic properties and their adaptation to the animate and inanimate environment. In order to understand the functioning of biological communities, it is necessary to conduct studies on the reproductive biology of specific species, as well as their physiological efficiency, and inter- or intra-specific interactions at all ontogenetic levels. In this context, it will be necessary to pay more attention to pathological and epidemiological phenomena. Application-oriented research in the field of marine biology deals with the effects of man-made pollution loads on marine ecosystems and develops concepts for the utilisation and protection of living resources. However, this is only possible if the organisms and their diversity are known. In the classical disciplines of taxonomy and systematics, there is a need for research in particular with regard to the poorly known habitats of the deep sea and the open sea, as well as the hydrothermal biotopes. Last but not least, studying the effects of specific factors such as UV radiation on the CO₂ binding capacity of plankton algae is also an important task.

It has turned out that long data series are necessary in order to distinguish reliably between man-made changes in ecosystems on the one hand, and seasonal or inter-annual variability on the other. Such data are currently available for an incomplete

set of parameters from monitoring stations covering the following locations: Helgoland roadstead, the Kiel Bay, the open Baltic Sea, and the Darss-Zingster bodden chain. Zoobenthos time series have been available for the shallow water of the Frisian tidal flats, the open German Bight and the Kiel Bight since the late 1960s. For the western part of the Baltic Sea, these time series show a continuous trend towards depletion, while they show opposite trends for the German Bay because of differences in eutrophication.

Long-term (biological) studies in the open ocean are indispensable for assessing the role played by the oceans in controlling the climate. In future, the data to be collected for this purpose at close temporal and spatial intervals will require longer ship use for repeated measurements at internationally coordinated stations and more cooperation in existing large-scale long-term monitoring campaigns (CPR).

Clarifying the structure of ecosystems, as well as the composition and diversity of their species, and improving our understanding of the factors controlling the energy and material flows will require both field observations and experimental studies. Since many marine organisms are extremely sensitive and since they cannot be preserved over longer periods of time without suffering damage, it will be necessary to develop modern methods which can be applied in sophisticated experiments carried out on research ships.

In the area of field ecology, research efforts will be focused on process-oriented, regional comparative studies of pelagic and benthic biocenoses, with the aim of discovering functional interdependencies. Particular importance will also have to be attached to the integration of biological components in circulation models of varying spatial and temporal resolution.

In view of the fact that there is still room for improvement in biological environmental monitoring, culture and laboratory experiments will have to be carried out with the following objectives in mind: exploring the specific claims on life and the environment of selected marine organisms; developing the scientific foundations for establishing "early warning systems" at the level of the individuals; and developing methods for assessing, as well as predicting and monitoring the ecological conditions in the European seas.

Physical Oceanography and Maritime Meteorology

Physical oceanography and maritime meteorology use basically similar methods, since the processes occurring in the ocean and in the atmosphere are governed by the same physical laws. For this reason, these two fields of research can be regarded as one entity which can therefore be dealt with jointly.

In the next few years, physical oceanography and maritime meteorology will deal with issues which are closely connected with global research programmes (WCRP, e.g. WOCE and TOGA) and which are incorporated in the activities of the European Community. The following processes will be priority research areas:

- Systems of currents in the Atlantic Ocean and the associated heat transport from the southern hemisphere to higher latitudes of the northern hemisphere. These studies will focus on the western marginal currents and their continuation, as well as the transition of the water masses from the warm water sphere to the subpolar and polar regions. The propagation of deep water and Mediterranean water will also play an important role.
- Processes in the ocean-atmosphere-cryosphere system which have an impact on the climate. Studies which will be conducted in this field will concentrate on observation programmes and model calculations of the thermohaline circulation, with the main emphasis being placed on thermohaline variations in the northern and southern Atlantic Ocean. In the North Atlantic, studies will focus on the European Arctic Ocean and the Barents shelf, as well as their interactions with the adjacent oceans. A primary objective in the northern Atlantic Ocean will be to understand the effects of ice formation on the convection and formation of deep water. In the southern Atlantic Ocean, research efforts will concentrate on the circumpolar current and the formation of antarctic bottom water. In addition, studies will be conducted at the ice edge, in polynyas and below the ice.
- Global water balance (GEWEX). In the next few years, research interest will be focused on the following issues: the fresh water balance of the ocean and its effect on thermohaline circulation; precipitation and evaporation, as well as water and water vapour transport in the atmosphere above the oceans and the polar sea ice regions.
- Maritime meteorological processes above the ocean, in particular in the polar sea ice regions. The purpose of the projects carried out in this field is to describe the exchanges of energy, impulse and substances between the ocean and the atmosphere, and to portray these flows in coupled models.
- Currents and mixing processes in the North Sea and the Baltic Sea and their effects on the chemical and biological conditions prevailing in these marginal seas, as well as identifying and predicting natural processes in coastal regions. The purpose of these studies is to improve our understanding of pollutant dynamics in near-shore ecosystems and to improve the monitoring of these sea regions.

The studies will include extensive field observations involving research vessels and aircraft, as well as drifting and anchored equipment. Research vessels will provide data on the distribution patterns of hydrographic parameters, as well as nutrients and trace substances. Satellite-based remote sensing equipment will help to obtain information on wide areas of the ocean surface. At the same time, model calculations will be carried out in order to improve our understanding of large-scale circulation patterns and the associated transport of substances, as well as major processes such as convection, ventilation and vortex diffusion.

Satellites are mainly used today in order to obtain data on temperature distribution patterns, phytoplankton and sediment concentrations in the near-surface ocean layer, as well as the propagation and concentration of sea ice. Microwave methods can be used to identify sea level variations of down to a few centimeters, and to record wave action. Altimetric measurements of water level variations make it possible to calculate large-scale geostrophic surface currents. In addition, such recordings also make it possible to reconstruct the wind direction and the wind force. The European ERS-1 satellite has helped to make major progress in the field of oceanographic remote sensing. The calibration, analysis and interpretation of the diverse data records requires remote sensing from aircraft and ground-truth measurements using ships; first and foremost, however, there is a need for model calculations to interpolate and assimilate the data. Simulations of the ocean currents for specific periods of time during the ERS-1 mission will be necessary in order to identify signals in various parts of the motion spectrum (general circulation, tides, wave action). Furthermore, satellites are used for determining the positions of drifting buoys and for transmitting data.

Remote measuring technology is also becoming more important in the submarine environment. Flow profile measurements by means of acoustic Doppler profile flow meters have evolved into an operational method in the past five years. Acoustic tomography, i.e. the penetration of water bodies by means of sound rays, is used to monitor temperature variations over long distances. This means that there is considerable scope for applying this method for monitoring large-scale climate changes in the ocean.

Section III.3.2.1 describes the objectives and priorities of the German Federal Government's promotion of research into fundamental issues of marine sciences.

II.3 National Research Institutions; German Research Foundation; Large-Scale Equipment

In the Federal Republic of Germany, marine research is performed at universities, federal and state-level institutions, national research centres and numerous scientific institutes.

Unless research activities are formalised in international or national projects, they are coordinated on an ad-hoc basis.

The wide range of basic marine research performed at universities provides an indispensable basis for research activities conducted at other institutions which focus more on specific themes and have a different organisation. The Federal Government safeguards and develops basic marine research in many ways, especially by contributing towards the budget of the German Research Foundation, by allocating funds under the University Construction Act and by providing large-scale equipment.

A. Institutions run by Federal Government departments

The **Federal Ministry of Education, Science, Research and Technology** operates the *Biologische Anstalt Helgoland* (BAH – Helgoland Biological Institute) in Hamburg. Pursuant to Article 91b of the Basic Law the ministry – together with the various state governments – also funds the national research centres as well as the research institutions included in the "Blue List". Among these are the *Alfred-Wegener-Institut für Polar- und Meeresforschung* (Alfred Wegener Institute for Polar and Marine Research) in Bremerhaven and Potsdam, funded together with the Free and Hanseatic City of Bremen and the State of Brandenburg, the *GKSS-Forschungszentrum Geesthacht GmbH* (Geesthacht Research Centre), financed together with the states of Schleswig-Holstein, Lower Saxony, Hamburg and Bremen, the *Institut für Meereskunde an der Universität Kiel* (Kiel University Institute for Oceanography), supported together with Schleswig-Holstein, the *Institut für Ostseeforschung an der Universität Rostock* (Rostock University Institute for Baltic Sea Research), funded together with the state of Mecklenburg-Western Pomerania, as well as the Research Institute of the *Senckenbergische Naturforschende Gesellschaft* (Senckenberg Society for Research in Natural Sciences) in Frankfurt, financed together with the state of Hesse (details see under section C).

The *Biologische Anstalt Helgoland* (Helgoland Biological Institute), a federal institute, comprises the departments of marine zoology, marine botany, biological oceanography, experimental ecology and marine microbiology. It operates institutions in Hamburg (headquarters), on Helgoland (marine station) and in List on Sylt (Tideland station). Research activities focus on the biological dynamics and interactive processes occurring in neritic ecosystems, the culture of marine organisms and the protection of the marine environment. The BAH provides a number of scientific services such as looking after German and foreign visiting scientists, providing places in courses and supplying land-based teaching and research institutes with pertinent marine material.

Through the *Umweltbundesamt* (Federal Environmental Protection Agency) the **Federal Ministry of the Environment, Nature Conservation and Nuclear**

Safety funds projects of applied research relating to the protection of the marine environment; the *Bundesforschungsanstalt für Naturschutz und Landschaftsökologie* (Federal Research Centre for Nature Conservation and Landscape Ecology) provides decision-making aids in the field of nature conservation and especially with regard to the protection of migrating species. Its field station on the Baltic island of Vilm (Internationale Naturschutzakademie Insel Vilm; INA – International Nature Conservation Academy on Vilm Island) helps translate the results of marine research into political action.

The **Federal Ministry of Transport** – through its *Bundesamt für Seeschifffahrt und Hydrographie* (BSH – Federal Maritime and Hydrographic Agency) – is responsible for the safety of shipping and coasts, for monitoring the marine environment as well as for oceanographic studies. These functions include hydrographic services such as water level forecasts, storm surge warnings, ice reports, tide predictions and seaway forecasts as well as the geomagnetic service. On the open seas, the ministry is also responsible for monitoring the pollutant concentration in sea water and sediments. The BSH runs the *Deutsches Ozeanographisches Datenzentrum* (DOD – German Oceanographic Data Centre) as well as – on behalf of the Federal Ministry for the Environment – the marine environmental data base. In addition, the BSH operates a network of automatic monitoring stations in the German Bay and off the Schleswig-Holstein and Mecklenburg-Western Pomeranian coasts. Other institutions under the jurisdiction of the ministry are the *Bundesanstalt für Gewässerkunde* (Federal Institute for Hydrology), *Bundesanstalt für Wasserbau* (Federal Institute for Waterway Engineering) as well as the *Deutscher Wetterdienst* (German Meteorological Service).

The **Federal Ministry of Economics** funds marine geological and geophysical research activities conducted by the *Bundesanstalt für Geowissenschaften und Rohstoffe* (BGR – Federal Institute for Geosciences and Natural Resources) in Hanover. Since 1958 the BGR has been doing worldwide geological research in shelf regions and along the margins of continental shelves as well as in the deep sea. Conducting parallel onshore and offshore activities (e.g. Ross Sea/North Victoria Land, Antarctica), the institute provides an optimal basis for the necessary integration of marine and terrestrial geoscientific studies. As a member of the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES) which are responsible for coordinating international cooperation in the geoscientific exploration of ocean floors through drilling, the BGR coordinates German activities under the International Ocean Drilling Programme.

The *Bundesforschungsanstalt für Fischerei* (Federal Research Centre for Fisheries) in Hamburg and Rostock, which is under the jurisdiction of the **Federal Ministry of Food, Agriculture and Forestry**, performs research in the areas of fishery and related sciences. Its function is to develop a scientific basis to serve as a decision-making aid to be used by the Federal Government in determining its

fisheries policy. This applies in particular to fishing quotas and measures designed to conserve fish stocks as well as to consumer policy in the food sector. In addition, the centre is to extend scientific knowledge in its research areas for the benefit of the general public. In particular, it is responsible for the biological monitoring of commercial fish stocks, the monitoring of concentrations of pollutants and other detrimental factors, the opening up of new fishing grounds as well as the development of new fishing techniques and maricultural processes. The centre also performs research with regard to food law regulations governing the quality of fish and fish products.

Being the only research institution under the jurisdiction of the **Federal Ministry of Defence**, the *Forschungsanstalt der Bundeswehr für Wasserschall- und Geophysik* (FWG – Federal Armed Forces Institute for Underwater Sound and Geophysical Research) has been entrusted with developing techniques to evaluate and forecast seaway, ocean layering and sediment transport as well as studying – in cooperation with research institutes of the member states of the Alliance – monitoring procedures to protect sea lanes as main international trading links. This involves improving data collection and transmission, including sensory analysis and signal processing, as well as forecasting the highly changeable marine monitoring performance which mainly relies on echo-sounding.

B. Universities and other institutions at state level

In almost all federal states, there are university institutes that are involved in marine research. However, only major institutions are listed below.

Berlin

After the *Institut für Meereskunde* (Institute for Oceanography) had been dissolved in the wake of World War II, marine research has mainly been continued at the **Freie Universität Berlin** (FUB – Berlin Free University) and the **Versuchsanstalt für Wasserbau und Schiffbau** (VWS – Berlin Model Basin). Their activities aim to set up joint research groups to study marine geosciences, the formation of marine deposits, marine resources and energy production as well as the protection of the marine environment.

In addition to fulfilling the classic functions of basic and applied research in these areas, the research group focuses on studying man-made environmental pollution and the environmental compatibility of human activities in the marine environment. In its work the group can rely on many years' experience gathered by the various partners, e.g.

- in geological, geochemical and geophysical studies of the ocean floor and superjacent waters (FUB, VWS),
- in studying the formation of marine deposits (FUB),
- in assessing environmentally compatible processes for extracting marine resources from shelf regions and the deep sea (VWS, Berlin Technical University),
- in exploring and assessing the environmental risk involved in the marine storage and carriage by sea of potential water pollutants (VWS, TUB).

There have been proposals to take advantage of this concentration of scientific potential and set up a centre for the protection of the marine environment in Berlin in cooperation with the higher education institutions in Clausthal and Freiberg.

The Versuchsanstalt für Wasserbau und Schiffbau (VWS – Berlin Model Basin) is owned by the state of Berlin. It concentrates chiefly on applied research. Since 1970 the centre has been working in the areas of marine pollutant control, developing environmentally friendly processes for extracting marine resources as well as developing and improving measuring devices to be used in marine geology and geophysics. It cooperates with the FUB in marine research, acts as an advisory body to the Federal Government on issues of pollutant control and maintains close contacts with the BGR and the BSH in Germany as well as IFREMER and CEDRE in France.

To perform its tasks the VWS uses extensive test facilities which not only permit the simulation of geophysical and hydromechanical processes, but are also very helpful in developing equipment and processes to be used in marine geology and in extracting resources. The centre also has a large library of chemical and physical parameters of water pollutants.

The Fachrichtung Rohstoff- und Umweltgeologie der FUB (FUB Resources and Environmental Geology Department) works in the field of marine geosciences chiefly with a view to studying the formation of deposits on the ocean floor. This process is critically influenced by the geological and geochemical interactions between the ocean floor and superjacent waters as well as between the lithosphere and the hydrosphere. The ocean expeditions required for this type of research are carried out in the framework of interdisciplinary and international co-operation.

Bremen

Most marine research projects in Bremen focus on basic research. They contribute towards climate and environmental research as well as towards research into the general theme of global change. These priorities are also reflected in plans for future research which – based on national and international cooperation – is primarily to tackle the following three issues:

- the ocean as one of the main components of the Earth's climate system;
- the oceans, in particular shallow coastal regions, as a source of food and natural resources;
- marine pollution caused by anthropogenic environmental factors.

Research activities focus on the Atlantic Ocean; but under national and international priority projects studies are also carried out in the Indian Ocean and the Pacific Ocean. In cooperation with other German coastal states, the North Sea countries and Third-World partners, research is increasingly directed at studying the scientific basis for protecting and utilising coastal waters.

In close cooperation with the **Alfred-Wegener-Institut für Polar- und Meeresforschung (AWI – Alfred Wegener Institute for Polar and Marine Research)** (see Section C) in Bremerhaven, the University of Bremen has set up joint research groups to study marine geosciences, marine biology as well as the physics and chemistry of the ocean and the atmosphere. The most recent newcomers in this field are the **Max-Planck-Institut für Marine Mikrobiologie (Max Planck Institute for Marine Microbiology)** (see section D) and the **Zentrum für Marine Tropenökologie (ZMT – Centre for Marine Tropical Ecology)**. The latter looks at the ecology of tropical neritic waters and coastal regions, in particular in Third-World countries.

Currently, the university is planning to set up a **Zentrum für Marine Umweltforschung (Centre for Marine Environmental Research)** as a cooperative scientific exercise of the natural scientists working in this area in Bremen. This project will also integrate humanistic scientists, economists and lawyers interested in environmental issues.

A fruitful interaction has developed between research and the marine metrology industry located in Bremen. This applies in particular to remote sensing, ocean floor surveying and automatic sensor technology which serve to monitor remote ocean areas as well as coastal regions and shallow waters.

Longer-term marine-geoscientific environmental and climate research activities are conducted under the special research programme 261 of Bremen University in cooperation with the AWI. New methods of training doctoral candidates focusing on marine research are being pursued in a postgraduate study course on "Material flows in marine geosystems". To intensify marine research activities in Bremen other working groups are being set up to study marine geosciences, marine engineering and marine microbiology.

In Hamburg, the institutions run by the state government, the Federal Government and the Max Planck Society provide a large oceanographic and climatological potential which is to be consolidated and increased in the long term by reorganising marine research. The institutions working in marine and climate research will gradually join to form a **Zentrum für Marine und Atmosphärische Wissenschaften (ZMAW – Centre for Marine and Atmospheric Sciences)** which will also coordinate some of their concepts. These considerations were triggered by the fact that the varied and complex tasks and the new sophisticated processes and technologies of marine and climate research call for existing resources to be pooled on an interdisciplinary basis.

In the first restructuring phase, the marine institutes of **Hamburg University** were united in a **Zentrum für Meeres- und Klimaforschung (ZMK – Centre for Marine and Climate Research)**. The ZMK is dedicated to free interdisciplinary marine, climate and environmental research. It is performing basic and applied research, especially in the areas of

- aquatic ecosystems
- ocean/atmosphere interactions
- structure and development of the subsoil of the seabed.

The ZMK cooperates closely with the **Biologische Anstalt Helgoland (Helgoland Biological Institute)**, the **Max-Planck-Institut für Meteorologie (Max Planck Institute for Meteorology)**, the **Deutsches Klimarechenzentrum GmbH (DKRZ – German Climate Computer Centre)**, the **Bundesamt für Seeschifffahrt und Hydrographie (BSH – Federal Maritime and Hydrographic Agency)**, the **Alfred-Wegener-Institut für Polar- und Meeresforschung (Alfred Wegener Institute for Polar and Marine Research)** and the **GKSS-Forschungszentrum Geesthacht GmbH (GKSS – Geesthacht Research Centre)**.

Plans for the future ZMAW also provide for a geographical network including the Helgoland Biological Institute, the Max Planck Institute for Meteorology and the DKRZ.

Marine research in Hamburg will focus on climate and environmental research both on a global scale (Global Change, protection of the deep-sea environment) and on a regional basis (LOICZ, North Sea and Baltic Sea).

To carry out marine and climate research projects, the Hamburg institutions can use the university-owned research vessel **VALDIVIA**. The logistics and administration of the **VALDIVIA** and of the research vessel **METEOR** are handled by the

"METEOR/VALDIVIA" coordination centre at the IfM Hamburg (Institute for Oceanography).

In addition, two special research programmes related to marine research are being implemented in Hamburg (see section II.3.E). An application has been filed for funds to be granted for a postgraduate course on "Tidal flats/ocean interaction".

Lower Saxony

In marine and environmental research, the **Carl von Ossietzky University in Oldenburg** concentrates on coastal and shallow waters. Research priorities at the *Institut für Chemie und Biologie des Meeres* (ICBM – Institute for Marine Chemistry and Biology) are the biological, geochemical and mathematical-physical analysis and modelling of recent and geological processes in marine systems. These fundamental, theoretical and experimental research activities provide the basis for more comprehensive research projects designed to study ecosystems and climate systems. Other ICBM activities are directed towards developing biotechnological processes. The *biology department* performs research into coastal and polar ecology, while the *mathematics department* uses statistical methods and modelling to study shallow waters. The *physics department* develops processes and equipment for remote sensing, hydroacoustics and biophysics which are then applied in marine research.

Several institutes of **Göttingen University** are involved in marine research and marine technology development activities. Since 1965 the sediment geology section has been studying interactions between sediments and organisms. In 1974 priority was shifted to reconstructing global climate and sea level fluctuations over the last 1 million years.

These scientific activities go hand in hand with the design and construction of samplers to be operated under extreme conditions: a pneumatic Vibro corer for an 18m core, a deep-sea piston corer for a 36 m core.

The working group on "Marine Technology and Marine Mineral Resources" (AMTUC) at **Technical University of Clausthal** looks at questions and problems of resources-oriented marine technology. Core areas are:

- raw material exploration and evaluation
- marine mining including processing and treatment, and
- offshore technology.

Most research activities are carried out in close cooperation with industry. They are designed to deepen the understanding of the development, distribution and value of marine resources as well as to develop technical processes and systems

for their extraction and processing. The Geotechnical Institute and the sediment geology section are also involved in the Ocean Drilling Programme (ODP). Applied sedimentology research is performed in cooperation with the Bundesamt für Seeschifffahrt und Hydrographie at the international dumping site for radioactive waste in the Iberian Basin.

At Hanover University various institutes perform marine and environmental research. Activities focus on coasts and nearshore areas including estuaries. The *Franzius-Institut für Wasserbau und Küsteningenieurwesen* (Franzius Institute for Waterway and Coastal Engineering) looks – among other things – at the effects of a possible rise in sea levels on coasts and coastal plains, at the changes and effects of man-made changes in nearshore areas as well as rivers and sea lanes including local changes in waves and currents. The studies are based on laboratory models and the evaluation of measurements using numerical processes. Research focuses on the fundamental principles underlying waves and wave forces which are being studied in the Large-Scale Wave Channel, a facility shared by the universities of Braunschweig and Hanover. The *Institut für Strömungsmechanik und Elektronisches Rechnen* (Institute for Fluid Mechanics and Electronic Computing) is developing extensive models to simulate morphological processes and changes in coastal waters. Special research is directed to understanding the transport and behaviour of suspended matter in estuaries. In addition, both institutes are cooperating closely under the special research programme 205 on "Coastal Engineering".

The **Forschungszentrum TERRAMARE e.V. (TERRAMARE Research Centre)** in Wilhelmshaven, which receives basic funding from the Lower Saxony Ministry for Science and Cultural Affairs, provides services for all institutions in Lower Saxony working in the field of marine research. The centre also coordinates interdisciplinary projects in basic research and research into the marine environment.

The **Niedersächsisches Landesamt für Ökologie – Forschungsstelle Küste, Norderney (Lower Saxony Board of Ecology – Coastal Research Station, Norderney)** which is under the jurisdiction of the Lower Saxony Ministry for the Environment performs applied research in coastal and shallow waters in Lower Saxony. It studies morphological and hydrodynamic processes including man-made changes and explores and analyses ecosystems and their interactions with abiotic factors. In addition to its original functions, the board is involved in numerous studies which form part of interdisciplinary cooperative research projects.

The **Institut für Vogelforschung, Wilhelmshaven und Helgoland (Institute for Bird Research, Wilhelmshaven and Helgoland)** looks into the ecology of marine birds. Current research is concentrating on food and population biology,

distribution over the oceans and contamination by pollutants. Special focus is on studying the suitability of birds for monitoring the marine environment.

Among the original tasks of the **Niedersächsisches Landesamt für Bodenforschung, Hanover (Lower Saxony Board of Soil Research, Hanover)**, which is under the jurisdiction of the Lower Saxony Ministry of Economics, Technology and Transport, is the geological exploration of marshes, tidal flats and islands. Under several geological research programmes designed to study deposits, the raw material potentials of sand, gravel and heavy minerals in the German part of the North Sea were explored and raw material reserves identified, in some cases in cooperation with industry.

Schleswig-Holstein

Several institutes of **Kiel University** are active in marine research and work closely together with the affiliated Institute for Oceanography and GEOMAR under the special marine research programmes 133 and 313 (for the *Kiel University Institut für Meereskunde* [Institute for Oceanography] see section II.3.C). The *Institut für Geophysik* (Institute for Geophysics) and the *Geologisch-Paläontologisches Institut* (Institute for Geology and Paleontology) concentrate their activities chiefly on marine geophysics and geology; scientists of the latter institute are also involved in the ODP.

The *Forschungs- und Technologiezentrum Westküste* (FTZ – West Coast Research and Technology Centre) in Büsum is a new interdisciplinary university institution which integrates the scientific activities of the working groups studying the Wadden Sea and its environment. Other contributors are the *Nationalparkamt Schleswig-Holsteinisches Wattenmeer* (Schleswig-Holstein Tideland National Park Board) and the BAH Wadden Sea station in List on Sylt. The *Forschungsstelle Meerestechnik im Institut für Angewandte Physik* (Marine Technology Research Centre at the Institute for Applied Physics) – which also has a working group at the FTZ – looks at the practical use of marine resources in energy technology and metrology as well as at environmental measuring techniques in coastal waters.

Dealing with questions of marine ecology is part of the work of the *Institut für Polarökologie* (Institute for Polar Ecology). The *Institute für Geographie und für Internationales Recht* (Institutes for Geography and for International Law) study issues of maritime economic and cultural geography and of international maritime law.

In 1987, **GEOMAR** was founded as a new research centre for marine geosciences at Kiel University in order to strengthen and enhance the position of marine geosciences in Germany. GEOMAR comprises four scientific departments:

- Geology of the marine environment
- Paleo-oceanology
- Marine geodynamics
- Volcanology and petrology

GEOMAR provides a growing number of central scientific services such as a marine-geoscientific information centre, a collection of seabed samples (GEOMAR Lithothèque), a computer and data processing centre as well as central laboratories equipped with modern instruments. The GEOMAR study centre is in the process of being set up. A new building is currently being erected for GEOMAR at the eastern shore of the inlet of Kiel Bight. The purpose of GEOMAR is to provide a bridge between basic academic research in selected scientific areas and applied research and services for marine geosciences, which are being built up together with the marine engineering industry. The private GEOMAR-Technologie GmbH (GTG) was founded to ensure the link with industry. This private company is responsible for technology transfer and acts as a mediator between industrial and basic research.

Mecklenburg-Western Pomerania

Apart from the **Institut für Ostseeforschung (Institute for Baltic Sea Research)** in Rostock-Warnemünde (see section II.3.C) it is mainly **Greifswald University and Rostock University** which deal with issues of marine research.

In keeping with the recommendations of the Science Council, marine and environmental research in Mecklenburg-Western Pomerania will geographically and thematically concentrate on the Baltic Sea and the Bodden area. Both regions are suited for fundamental interdisciplinary research and are being studied in a cooperative research exercise named "Mecklenburg-Western Pomeranian Coast". In view of the increasing pollution of the Baltic Sea, its coastal waters and its hinterland, as well as the concepts for the preservation of the Earth's largest brackish water ecosystem agreed upon within the framework of HELCOM and of bilateral agreements, research is also of great economic and political significance. It can make important contributions within a Baltic Sea research network and provide the basis for supraregional comparisons with other brackish water regions (Science Council 1991).

The **Greifswald** contributions towards marine research are currently concentrating on studying exchange processes in the Greifswald Bodden and the Oder estuary.

Among other things, research is looking at the influence of suspended matter and sediments in the Oder estuary on the binding and mobilisation of heavy metals, thus contributing towards analysing exchange processes.

The nutrient exchange between pelagic and benthic regions (with different sediment types), their exposure to the effects of the macrozoobenthos, transport and mixing processes, as well as exchange processes at the water/air interface, are other issues that need to be explored. Another objective is mapping the macrophytobenthos in the Greifswalder Bodden by means of scanner evaluation.

The **biology department of Rostock University** deals with fundamental questions relating to the ecology, biology and taxonomy of animals in the Baltic, with the experimental analysis of the buffer capacity and flexibility of microbial trophic structures in brackish water ecosystems having different trophic levels, as well as with the autecology and physiological and ecological performance of selected invertebrates in brackish waters.

Furthermore, faunistic-ecological, taxonomic and zoogeographic studies are carried out in temperate and tropical ecosystems (upwelling regions off Northwest Africa, the Mozambique Channel, the Gulf of Aden, the Shatt Al-Arab/the Persian Gulf).

C. Institutions Funded by Federal and State-Level Governments

a. National Research Centres

In 1980, the **Alfred-Wegener-Institut für Polar- und Meeresforschung (AWI – Alfred Wegener Institute for Polar and Marine Research)** was set up in Bremerhaven as a foundation under public law. After German unification, it was extended to include the Potsdam Research Centre. With the FS POLARSTERN, the AWI has a powerful tool to study the physical, chemical and biological structures and processes in polar seas including pack ice regions. Research focuses on:

- studies of the physical interaction between the atmosphere, ice and the oceans;
- the analysis of marine ecosystems with their complicated interactions between environmental factors and living organisms on the ocean floor, also in non-polar waters;
- studies of the subsoil of the ocean floor of the polar Atlantic Ocean and its continental boundaries.

In the first research area, physical objectives prevail, while in the second area research centres on biological and chemical questions, and in the third area on geoscientific issues.

The AWI cooperates closely with the universities of Bremen, Hamburg, Kiel and Oldenburg as well as with institutions in Argentina, France, the U.K., Russia, the Netherlands, Norway and the United States dealing with similar issues. More than 400 staff, among them 150 scientists including doctoral candidates, work under the research programme and/or fulfill other functions at the national and international levels.

The staff of the institute play a prominent part in teaching marine study courses at Bremen University.

Research into material and energy fluxes performed by the **GKSS-Forschungszentrum Geesthacht GmbH (GKSS Geesthacht Research Centre)** focuses on the hydrological cycle, chiefly in the atmosphere, but also in the Elbe river and its upper course and estuarine environment, as well as in the Wadden Sea and in coastal regions. Specific priority has been given to analysing the life-cycles of substances in the Elbe estuary as well as to mapping potential pollutants in the Wadden Sea. The focus of these studies is on the interactions and interdependences of life-cycle analyses between the different regions.

These activities are complemented by climate research which, for the time being, is concentrating on the hydrological cycles studied in BALTEX (Baltic Sea Experiment), thus contributing to exploring atmospheric inputs of substances to the Baltic Sea, its entire catchment area, as well as the Elbe drainage area.

For marine monitoring, automatic monitoring stations designed to detect potential pollutants all over the North Sea and the Baltic Sea (MERMAID) are being developed in cooperation with other research institutions and industry. Subsea monitoring stations, which can fulfill functions similar to MERMAID, but under water, are in the conceptual phase.

b. Institutions Included in the "Blue List"

Federal and state governments jointly fund the institutes included in the "Blue List". These are institutions of supraregional importance whose activities are in the national scientific interest. The host states and the Federal Government finance the marine research institutions described below on a 50:50 basis.

The **Institut für Meereskunde an der Universität Kiel (IfM – Kiel University Institute for Oceanography)** is the largest marine research institute in Schleswig-Holstein. Its ten departments perform basic marine research worldwide, studying physical, chemical and biological marine phenomena and processes as well as ocean/atmosphere interaction. Only marine geosciences are not covered by these activities.

Many research projects take an interdisciplinary approach. This applies in particular to research projects carried out jointly with the university under special research programmes 133 und 313.

A considerable number of activities also fit in well with international programmes like JGOFS, WOCE and GEWEX as well as with international Antarctic research. In addition, application-related topics are being studied such as marine environmental research, the use of marine food sources and mariculture. In one research project which extended over several years, the IfM developed the basis for biological monitoring of the Baltic Sea. The institute is also involved in teaching activities at the Christian-Albrecht-Universität Kiel. It is considered to be the institution offering the most comprehensive marine study courses in Europe.

The **Institut für Ostseeforschung, Warnemünde (IOW – Institute of Baltic Sea Research)** at Rostock University is chiefly studying the Baltic Sea as an ecosystem. It also intends to carry out comparative oceanographic studies in selected regions of the world's oceans. In addition to basic research, which forms the centre of the IOW's activities, the institute contributes to monitoring and assessing the current status of the Baltic Sea. Its activities form part of national and international cooperation exercises in Baltic Sea research.

The long-term research programme of the IOW centres upon the following areas:

- the exchange of water between the Baltic Sea and the North Sea, as well as oxygen supply of deep waters,
- the exchange of energy and substances between coastal waters and the open waters of the Baltic Sea,
- processes in superjacent water and at interfaces,
- the paleo-oceanographic development of the Baltic Basin,
- monitoring of the marine environment of the Baltic Sea.

The aim of the interdisciplinary approach to these activities is to model the ecosystem of the Baltic Sea on the basis of observations and theoretical research. The IOW will act as a coordinator of Baltic Sea research at national and international level. Institute staff teach oceanography at the universities of Rostock and Greifswald.

In addition to other activities, the **Forschungsinstitut Senckenberg (FIS – Senckenberg Research Institute)** in Frankfurt (Main), with its department for marine research in Wilhelmshaven, performs basic research in the fields of marine biology (Frankfurt and Wilhelmshaven) and marine geology (Wilhelmshaven), including environmental issues. Preferred research objects of the Wilhelmshaven department are the intertidal zone, the beaches and the coastal shelf, with special importance being attached to comparative studies of coastal and deep-water zones

with different exposure to tides and waves. The Frankfurt institute concentrates on both coastal and deep-water taxonomical and ecological research. Special attention is paid to the North Sea, the Mediterranean, the western part of the Indian Ocean and the Red Sea, as well as to East Asian waters. Research activities are carried out with the Institute's own seagoing craft and – under major priority programmes – with the FS METEOR, the FS POSEIDON and other vessels. Particular attention is paid to cooperation with Third-World countries.

D. Max-Planck-Institute, Deutsches Klimarechenzentrum (Max Planck Institutes, German Climate Computer Centre)

The *Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V.* (Max Planck Society for the Advancement of Science), which is financed by the Federal Government and state-level governments on a 50:50 basis, runs about 60 institutes (MPIs) and research units which are largely independent and perform basic research only. Two of these institutes are more deeply involved in marine research.

The **MPI für Marine Mikrobiologie (MPI for Marine Microbiology)** in Bremen started its activities in 1992. Its work focuses mainly on:

- microbial conversions of inorganic and organic compounds at marine and other aquatic locations,
- the ecology, physiology and biochemistry of microorganisms and biocenoses of microorganisms,
- interactions between physical, chemical and microbial processes.

Until a new building is completed on the university campus, the new institute is housed in the *Bremer Innovations- und Technologiezentrum* (BITZ – Bremen Innovation and Technology Centre). When completed, the institute will employ 20 scientific and 40 technical staff. There are plans to cooperate closely with the AWI, whose research vessel VICTOR HENSEN is to be used by the MPI as well, and with other institutions.

The **MPI für Meteorologie (MPI for Meteorology)** in Hamburg cooperates closely with Hamburg University and the *Deutsches Klimarechenzentrum* (DKRZ – German Climate Computer Centre). The institute studies issues of natural climate variability, remote sensing of energy fluxes at the ocean/atmosphere interface and the global modelling of aerosols, and develops regional climate models.

The **Deutsches Klimarechenzentrum GmbH (DKRZ – German Climate Computer Centre)** was founded on 1 January 1988. The current members of the partnership are the Max Planck Society, the University of Hamburg, the GKSS-

Forschungszentrum Geesthacht GmbH (Geesthacht Research Centre) and the *Alfred-Wegener-Institut für Polar- und Meeresforschung* (Alfred Wegener Institute for Polar and Marine Research). They pay about 60 percent of the annual operating costs (computer time), amounting to user fees of approx. DM 12 million. The Federal Government – represented by the Federal Ministry for Education, Science, Research and Technology – contributes the balance of about 40 percent by financing contracts awarded to the DKRZ. The ministry also pays for annual investments of currently DM 6 million.

The objective of the DKRZ is to maintain the current leading position of German climate research and to get effectively involved in the rapidly expanding World Climate Research Programme. The primary task of this supraregional service institution is to provide technical and scientific support for computer simulations using sophisticated numerical models for climate research and related areas.

There is a debate currently about whether the DKRZ should be developed into a Global Change Computer Centre. The necessary basis would be "Europeanisation" of climate research, which the Federal Government is striving for.

E. Deutsche Forschungsgemeinschaft (DFG – German Research Foundation)

The DFG is an autonomous research promotion organisation which is administered by scientists and is not itself actively involved in research. The funds for research promotion are provided by the Federal Government and state-level governments.

The major coordination body for cooperation in marine research is the *Senatskommission für Ozeanographie* (Senate Committee on Oceanography). Its terms of reference have been defined as follows:

"The Committee on Oceanography shall plan and coordinate the DFG's activities in the field of marine research and look after pertinent priority and special research programmes. In particular, it shall be in charge of matters relating to the research vessel METEOR as well as the planning, implementation and evaluation of METEOR expeditions. It shall also deal with matters of the Scientific Committee on Oceanic Research (SCOR) of the International Council of Scientific Unions (ICSU)."

All marine disciplines and the major marine research institutions and stations in Germany are represented on the Committee on Oceanography.

There is a direct link between the functions of this committee and those of the *Senatskommission für Atmosphärische Wissenschaften* (Senate Committee on

Atmospheric Sciences) regarding questions of ocean/atmosphere interactions and maritime meteorology; another link exists with the Senatskommission für Geowissenschaftliche Gemeinschaftsforschung (Senate Committee on Cooperative Geoscientific Research) in matters of marine geosciences. Coordination among the various committees is ensured – among other things – by dual membership.

The committees discuss research programmes and promotion schemes and submit recommendations to the DFG Senate (which established them), to the Executive Board and the Grants Committee, and – in some cases – to other institutions as well. The Senate then determines which promotion programmes are to be established, while the Grants Committee decides on the funding of research projects under these promotion programmes.

Special research programmes (SFBs)

SFB 133 "*Warmwassersphäre des Atlantiks*" (Warm Water Sphere of the Atlantic Ocean), Kiel

Research into heat transport from the tropics to temperate latitudes through general Atlantic circulation.

SFB 261 "*Der Südatlantik im Spätquartär*" (The South Atlantic in the Late Quaternary), Bremen

Reconstruction of the development of South Atlantic current and production systems in the late Quaternary with a view to understanding long-term climate processes.

SFB 313 "*Veränderungen der Umwelt: der nördliche Nordatlantik*" (Changes in the Environment: the Northern Part of the North Atlantic), Kiel
Research into the changeability of the environment and of living conditions on different temporal and spatial scales in the European Arctic Ocean and adjacent regions.

SFB 318 "*Klimarelevante Prozesse im System Ozean-Atmosphäre-Kryosphäre*" (Processes in the Ocean-Atmosphere-Cryosphere System Affecting the Climate), Hamburg

Projects on parametrising sub-scale processes in climate models.

SFB 327 "*Wechselwirkungen zwischen abiotischen und biotischen Prozessen in der Tide-Elbe*" (Interactions between Abiotic and Biotic Processes in the Tidal Elbe River), Hamburg

Projects aimed at understanding and quantifying estuarine processes that are important for the ecosystem of the tidal Elbe river.

The DFG has set up the following marine research programmes:

The federal research vessel METEOR is operated as an "auxiliary research facility" (see Section F for funding). Under the "METEOR expeditions" priority programme, the METEOR helps carry out basic research projects in all disciplines worldwide in close cooperation with other countries. The METEOR operates mainly in the ice-free Atlantic Ocean as well as – albeit less frequently – in the Mediterranean and the Indian Ocean.

Financing the "Ocean Drilling Programme/Deep Sea Drilling Project" priority programme (in some cases with special BMBF funds) ensures the continuous participation of German marine-geoscientific working groups in this international programme.

Two other priority programmes also cover some marine science aspects: Research under the programme on "Antarctic research including comparative studies in Arctic ice regions" focuses on the oceanography of the South Polar Sea as well as on the physics, chemistry, biology and sedimentology of the Weddell Sea. The priority programme on "Physical methods of atmospheric and hydrospheric remote sensing" includes activities on the interaction of microwaves and water surface.

Postgraduate courses constitute the most recent promotional tool of the DFG. A postgraduate course at Bremen University studies "Material flows in marine geosystems", which comprise the entire process from the input of materials into the ocean to their deposition in sediments. Parts of another postgraduate course on the "Dynamics of global cycles in the Earth system" held at Kiel University include marine science activities. Lawyers and scientists of Kiel University work together in a postgraduate course on "National and international environmental law".

Applying the so-called Normal Procedure, the DFG also supports projects on climate research, physical oceanography, marine biology as well as marine geosciences.

Detailed descriptions of promotion programmes, objectives, total promotional funds, participating scientists as well as the subject matter of the funded projects are provided in the DFG annual reports (Volume 2 "Programme und Projekte").

F. Large-Scale Marine Research Equipment

The most important instruments of marine research include research vessels specifically built for this purpose. A list of these vessels including some important data is provided in the Annex.

In the past, the BMBF bore the cost of more than DM 400 million incurred in designing and building the large specialised vessels. Basically, the ministry also pays for the current operation of most research vessels. Furthermore, marine and

polar research has used a satellite station in Antarctica since 1991 which directly receives the data of the first European Remote Sensing Satellite ERS-1 collected over the sixth continent and permits the immediate local evaluation of some of these data.

By providing this large-scale equipment, the Federal Government enables many research groups to perform their activities at the highest technical level and thus take a leading position worldwide in many areas. **POLARSTERN**, **METEOR** und **SONNE** are research vessels that operate all over the world.

PFS POLARSTERN: With an overall length of 118 meters, the polar research vessel POLARSTERN is the biggest German research vessel. The keel was laid down at the HDW shipyard in Kiel late in summer 1981, and from February 1982 onwards the vessel was equipped at Nobiskrug in Rendsburg. Building costs amounted to about DM 190 million. The POLARSTERN is registered in Bremerhaven and operated by the *Alfred-Wegener-Institut für Polar- und Meeresforschung* (Alfred Wegener Institute for Polar and Marine Research). Since her commissioning in autumn 1982, the POLARSTERN has shown repeatedly on ten voyages to Antarctica and nine voyages to the Arctic that she is quite rightly considered the most powerful polar research vessel in the world. The fact that she was the world's first research vessel with a conventional propulsion system to reach the North Pole on 7 September 1991 contributed considerably to this reputation. In addition to a crew of 41 the POLARSTERN accommodates up to 70 scientists who can do basic atmospheric, oceanographic and geological research work on board. Owing to her specific design, the POLARSTERN can pass through ice layers with a thickness of 1.4 meters at a speed of 5.2 knots.

FS METEOR: Since the end of the last century, several research vessels have been named METEOR in Germany. The 'new' METEOR, which was commissioned in 1986, is the fifth vessel in this series and is registered in Hamburg. The METEOR was built at the Schichau shipyard in Travemünde for about DM 100 million. In the past seven years, she has gone on 24 research voyages in the Atlantic Ocean, the Mediterranean and the Indian Ocean. The vessel accommodates a crew of 30 as well as 30 scientists. All in all, about 2,100 scientists have so far worked on the METEOR. The operating costs are shared between the DFG and the BMBF on a 70:30 basis. The vessel can be equipped for all types of oceanographic, marine-geological and atmospheric studies. Apart from the SONNE, she is the most important instrument for basic research at all latitudes, except for the polar regions.

FS SONNE: The research vessel SONNE (built in 1969) is the property of the SONNE shipowning partnership, and is registered in Bremen. In 1991, the vessel was completely rebuilt at the Schichau-Seebeck shipyard in Bremerhaven; her overall length was extended by 10.8 meters to 97 meters, and the latest research

equipment was installed on board. The cost of the basic scientific and technical equipment, which amounted to about DM 20 million, was borne by the BMBF. The large-scale equipment installed on board the SONNE includes a Hydrosweep multi-beam echo sounder and a Parasound sediment echo sounder, including the most recent data processing software, satellite and navigation systems, networked computer systems to collect, process and display scientific and nautical data, as well as an X-ray fluorescence spectrometer and a diffractometer. The FS SONNE is the first German research vessel to use a dynamic positioning system. She, too, can accommodate 30 scientists. By the end of 1993, the vessel will have undertaken more than 90 expeditions. The FS SONNE is mainly used for studies in marine geosciences, but she meets all the technical requirements for missions in the fields of oceanography, marine biology, marine chemistry as well as maritime meteorology. The SONNE operates chiefly in the Pacific Ocean, the Indian Ocean and the Atlantic Ocean.

Satellite receiving station: In the framework of research cooperation with the Republic of Chile, and together with the Federal Ministry of the Interior (BMI), the BMBF built the German O'Higgins satellite station in Antarctica in 1991. So far, the BMBF has spent about **DM 27 million** to help plan, build and operate the station, which has been owned by the DLR (German Aerospace Research Establishment) since 1993. Scientists man the station several times a year in order to record and store the data provided by the various remote sensors for monitoring campaigns conducted under BMBF R&D projects; in some cases the data are already processed on site, with the data of the Synthetic Aperture Radar (SAR) being of particular importance. This sensor is the first one to make precise recordings and measurements of the Earth's surface regardless of cloud cover. The data transmitted by the Japanese JERS satellite and by the satellite generations succeeding the European ERS-1 will be received by this station as well.

II.4 International cooperation

As they are looking for new resources and developing a growing scientific understanding of global correlations, many countries – industrialised nations and Third-World countries alike – are becoming more and more interested in marine research and monitoring. The expenditure required (for operating research vessels etc.) as well as the necessary international exchange of information and data necessitate international cooperation, either on a multilateral basis or with individual states. In many areas of marine research international cooperation relies on scientists to take the initiative. Designing programmes and exchanging results are activities that receive considerable support from the organisations united in the International Council of Scientific Unions as well as from intergovernmental organisations; without these bodies, such activities could not be carried out.

The Paris-based **Intergovernmental Oceanographic Commission (IOC)** plays a prominent role in **multilateral intergovernmental cooperation** in the field of marine research. Being the central marine research organisation of the United Nations, it develops, recommends and coordinates scientific programmes and marine services (data exchange, marine monitoring, mapping) and promotes setting up marine research in developing countries. In the framework of UNESCO, the IOC enjoys "functional independence"; it has 117 members. The Federal Republic of Germany actively supports the work of the IOC. German scientists are involved in almost all IOC programmes and bodies, e.g. in the discussions on a Global Ocean Observing System (GOOS).

A number of other UN organisations carry out marine programmes as well. One of the functions of the *United Nations Food and Agriculture Organisation (FAO)* is to preserve, make optimal use of and improve marine food resources.

The *International Council for the Exploration of the Sea (ICES)* mainly initiates research into the environment and the fish stocks in the north-east Atlantic and the Baltic Sea. Studies by the member states provide the scientific basis for fish stock management (e.g. under the EC fishery regime). ICES advises international commissions on how to prevent marine pollution.

The international *Ocean Drilling Programme* (see section II.2), in which the Federal Republic of Germany is a partner, is one of the most successful geoscientific cooperative programmes, and uses drillings to explore the seabed.

The *CIESM (Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée)*, an intergovernmental organisation based in Monaco, is involved in scientific exploration of the Mediterranean.

The *Marine Science and Technology (MAST)* programme carried out by the EC plays a central role in **European cooperation** (see section III.4 and Annex).

International cooperation under the umbrella of **non-governmental science organisations** – especially the *International Council of Scientific Unions (ICSU)* – is of particular importance for marine research. The German Research Foundation is a national member of ICSU, promoting German participation in subsidiary organisations and international scientific associations for physical (IUGG), physical/chemical (IAPSO) and biological (IABO) oceanography as well as for meteorology (IAMAP) and geology (CMG). To integrate the activities of the various disciplines into a global marine research exercise ICSU set up the *Scientific Committee on Oceanic Research (SCOR)* which supports the advancement of marine research worldwide through numerous working groups.

Bilateral cooperation with individual states is just as important as multilateral collaboration. Framework agreements on scientific and technological cooperation as well as other accords permit an extensive exchange of experience and the

flexible implementation of cooperative projects, e.g. with France, Japan and the People's Republic of China. Recently, cooperation with the states of the former Soviet Union has been expanded as well. Closer cooperation with Russia and the Baltic republics as well as Poland has provided a new impetus for marine research in Arctic waters and the Baltic Sea.

A list of bilateral agreements relating to marine research is given in the Annex.

Marine research is gaining increasing importance for the **countries of the Third World**. More and more coastal states are interested in establishing or developing their own research activities to record the local marine environment and create the basis for utilising marine resources. This situation represents an opportunity for German marine research. The Federal Government has already supported several oceanographic and fisheries research institutes in developing countries under technical cooperative programmes. Among other things, it provided funds for research vessels, for the scientific equipment of institutes and for the secondment of German advisers. The aim for the future is to integrate these countries into international project activities. On the German side, for instance, the *Zentrum für Marine Tropenökologie* (ZMT – Centre for Marine Tropical Ecology) in Bremen might act as a partner in such cooperative schemes.

The BMBF also finances special continuing education courses under the TEMA Programme (Training, Education and Mutual Assistance) organised by the IOC of UNESCO. Here, cooperation with small and medium-sized riparian states of the Indian Ocean has developed into a priority. Another region with which Germany is collaborating is Latin America.

Expeditions of German research vessels to tropical regions provide an opportunity for scientific cooperation and the exchange of a wide range of information with developing and newly industrialised countries. Examples are geoscientific studies conducted by the **FS SONNE** when exploring marine resources and marine sedimentation processes, and the expeditions of the **METEOR** and the **VICTOR HENSEN** designed to study issues of basic marine research, survey the ocean floor, explore biological aspects of fishing and introduce new methods for monitoring marine pollution and overfertilisation.

II.5 Recent trends in the Law of the Sea

For a long time, the basis of the Law of the Sea used to be the principle of the freedom of the seas which comprised not only the freedom of navigation and the freedom of fishing, but also the freedom of marine research. The most recent development of maritime law, however, reflects the conflicting interests of different states: While the maritime powers were striving to make free use of the largest possible area of the sea, some coastal states – as a result of economic and security

considerations – favoured a concept which guaranteed them the control and exclusive use of coastal waters. As a result of this constellation of interests, maritime zones have developed where the coastal states exercise rights and powers whose scope decreases as the distance from shore increases. This development was brought to a preliminary end with the conclusion of the Third United Nations Conference on the Law of the Sea in 1982.

This conference and previous Law of the Sea conferences have produced the Law of the Sea Convention which, however, has not yet entered into force even though it was adopted eleven years ago. Although most countries – as well as organisations like the EC – have signed the Convention, not all of them have ratified it. By mid-1993, only 56 of the 60 ratifications required to put the Convention into force had been effected. Current forecasts expect the Convention to enter into force in about two years' time. Like the USA and the U.K., the Federal Republic of Germany has neither signed, nor acceded to, the Law of the Sea Convention, the obstacle being its section on deep-sea mining. On the other hand, right from the very beginning the German Federal Government welcomed the other elements of the Convention and hence international maritime law proper as well as the legal regime relating to marine research, the protection of the marine environment and the settlement of disputes. This is why Germany has been actively involved in the informal dialogue initiated by the Secretary-General of the United Nations in 1990 which addresses the controversial regulations contained in the section on deep-sea mining, especially the provisions relating to the Seabed Authority, production restrictions and technology transfer. After the collapse of the Soviet Union, many countries in the Second and Third Worlds have adopted more market-driven philosophies, so that this dialogue now stands a better chance of contributing towards clarifying the most important controversial issues. But so far it has not been possible to achieve a breakthrough; many countries have already ratified the Convention as it stands, which renders it more difficult to make amendments to its text and thus poses an additional problem at the present stage. Nevertheless – and in spite of the fact that commercial deep-sea mining is now expected to begin rather at a later date – the German Federal Government is continuing its efforts to develop deep-sea mining regulations that are acceptable to all parties, even before the Convention takes effect.

Although the Law of the Sea Convention has not yet entered into force in its entirety, many of its provisions are already being complied with in general practice. This also applies to the legal regime governing marine research. The Convention confirms the right to perform scientific marine research and obliges countries to promote and facilitate the implementation of such research. At the same time it guarantees coastal states the right to regulate the exercise of marine research in territorial seas as well as in the exclusive economic zone and the continental shelf zone, while already containing certain constraints to be considered when drawing

up such regulations. In particular, the Convention requires that permits to be granted under normal circumstances be applied for at least six months prior to the scheduled beginning of the project concerned and that detailed information on the project, the vessel, as well as the participating persons and institutions be submitted. In addition, the Convention stipulates that the right of the coastal state concerned to participate in the research project has to be guaranteed, and that reports and evaluations have to be submitted to the coastal state on completion of the project. These provisions, which restrict the rights of the coastal states in those zones that have been redefined by the Law of the Sea Convention, prevent the coastal states from adopting and enforcing laws without any international control which might hinder scientific marine research. On the other hand, observing these provisions has in some cases imposed new administrative burdens on research. This also applies to the EC countries, some of which have made information requirements for research permits more stringent and extended the application period.

The German Federal Government is making efforts to counteract such trends. At the consultative talks on defining exclusive economic zones in the North Sea, it made sure that the establishment of such zones did not change the littoral states' existing regulations on granting research permits to the detriment of research and that the states concerned cooperate with a view to harmonising and simplifying their legal regimes. The German Federal Government also supports an initiative of the EC Commission which aims to replace the current compulsory permit by a notification among Member States, to be submitted three months prior to the beginning of the research project, and to provide for a one-month term of preclusion for possible objections by the coastal state concerned. These endeavours are complemented by other efforts to introduce simplified licensing procedures for research projects by way of multilateral conventions. The new Helsinki Convention on the Protection of the Marine Environment in the Baltic Sea Area, for instance, invites the states that are parties to the Convention to harmonise their licensing procedures in order to facilitate research and monitoring. A recommendation submitted by the Helsinki Commission to these states proposes that permits should be valid for one year and that they should be granted for more than only one research expedition at a time.

Finally, at the bilateral level the German Federal Government also tries to work towards regulations favouring marine research. When problems in licensing research projects occurred in some cases in the past, they were usually solved in cooperation with the scientific institutions concerned and the participating researchers, so that almost all the planned projects could be implemented. Such cooperation will continue to be indispensable, so that issues arising in relation to the licensing of individual projects can be solved in time before the actual project starts. In this context, coastal states often attach special importance to the involvement of their scientists and early reporting on previous research projects.

III. The Programme of the German Federal Government

III.1 The Need for Governmental Funding

The complexity and the importance of the regional and global problems associated with the climate and environmental pollution, as well as the need to preserve our resources which ensure our own survival, justify the German Federal Government's extensive funding of marine research as a long-term commitment. Both basic research and the more preventive problem-oriented research efforts are promoted by means of public funds in all countries, including Germany. In this context, the German Federal Government and the state-level governments should jointly develop or maintain structures which are designed to provide optimum solutions to the questions to be resolved, including protection of the coasts which is a task laid down in the German Constitution. It is only in the field of technology development for marine research and monitoring and in fields in which potential commercial utilisation of marine raw materials or maritime traffic interests play a major role that the industrial sector can be expected to show substantial interest.

There is also room for governmental promotion in fields in which the commercial utilisation of the ocean can lead to risks, e.g. the storage of waste on the ocean floor or the exploitation of submarine deposits. In these fields, it is the task of Government to pursue anticipating technology assessment in order to draw attention to potential risks for the marine ecosystem and, where necessary, to adopt legislation in order to eliminate these risks altogether or keep them within reasonable limits.

With its accession to a number of international agreements, Germany has committed itself to protecting the oceans. The Helsinki Convention for the Protection of the Marine Environment of the Baltic Sea (HELCOM), as revised in 1992, and the Convention for the Protection of the Marine Environment of the North-Eastern Atlantic Ocean (currently still referred to as the Oslo and Paris Conventions) provide for, inter alia, closer research cooperation among the parties to the agreements. In addition, the countries which participated in the Third International North Sea Conference in 1990 agreed to continue to expand their knowledge and findings about the ecosystem of the North Sea as a basis for future measures.

Last but not least, the results of the United Nations Conference on Environment and Development, which was held from 3 to 14 June 1992 in Rio de Janeiro, also suggest that research efforts should be stepped up in certain fields. This includes more detailed research into the role of the oceans as a carbon sink and the prerequisites for improving predictions of natural and man-made changes in the oceans, the seas and the coastal regions.

III.2 Funding Instruments

The German Federal Government promotes marine research at two different levels.

Basic funding of institutions

The German Federal Government as well as Germany's federal states use the instrument of basic funding to meet long-term objectives.

Basic funding is provided to specialised institutions, large-scale research institutions or blue-list institutes. Large-scale research institutions and "blue-list" institutions are funded jointly by the German Federal Government and the federal states, with varying shares of each of the two sources of funds (see also II.3.G). The research of these institutions which is financed by this basic funding is designed to provide contributions towards solving fundamental or problem-related and application-oriented issues.

Direct project promotion

Invariably, the German Federal Government sponsors specific projects **for a limited period of time only**. The purpose of this type of funding is not to promote research across the board, but to make contributions towards solving specific problems. The idea underlying this approach is that such promotion may "trigger" research into new structures and new topics whose long-term funding will then be assumed by other sponsors (e.g. the federal states).

Collaborative research plays an important role in the framework of project promotion. Collaborative research is a highly effective tool for initiating multidisciplinary cooperation in specific fields, either between various research institutions such as universities, large-scale research institutions and Max Planck institutes, or between such institutions and industry (cooperative industrial research). The advantage of such collaborative research efforts is that the mutually complementary human and infrastructural resources available in specific disciplines can be put to optimum use when dealing with a specific problem.

The promotion of **individual projects** is usually granted low priority only. However, it is quite possible for individual projects to be sponsored if there is particular governmental interest in the implementation of a given project or in the expected result of the project. There may be such interest, for instance, in projects carried out in the framework of international commitments or cooperative ventures.

III.3 Measures

The measures initiated by the German Federal Government are oriented towards the research policy objectives and the global goals described in Section I.

III.3.1 Structural Measures

The German Federal Government defines its role as follows:

- to coordinate national activities through the BMBF,
- to provide basic funding for basic and application-oriented research and activities in specific sectors,
- to provide funding for particular priority topics and for the development of specific structures,
- to coordinate and promote international activities,
- to support the development and transfer of technology,
- to provide a comprehensive infrastructure (e.g. ships, etc.), and
- to translate R&D findings into political decisions.

This leads to some major general structural measures which the German Federal Government intends to implement in the context of the present "marine research" programme.

More specifically, this will include the following actions:

1. Merger and interinstitutional coordination of national marine research activities based on an overriding concept (by means of establishing a corresponding body)

In its opinion on the promotion of marine research in the northern German federal states (1989), the *Wissenschaftsrat* (Advisory Board of Scientists) stated that the decentralised and pluralistic structure of German marine research was basically adequate. In the interest of making optimum use of the marine research resources available at various locations in the Federal Republic of Germany, the *Wissenschaftsrat* felt that there was a need to make full use of the scope for coordination by the German Federal Government and the governments in Germany's various federal states. The KONFERENZ LEITENDER MEERESFORSCHER NORDDEUTSCHLANDS (KLMN – CONFERENCE OF LEADING MARINE RESEARCHERS IN NORTHERN GERMANY), which was established by the ministers of science of Germany's northern federal states, has proven to be a useful instrument for exchanging information about marine research activities. According to the

Wissenschaftsrat, the coordination concept which was developed by the KLMN has already led to first attempts at defining research priorities for the various locations.

Against the background of increasing international cooperation and the need for a greater involvement of relevant inland research resources, the BMBF intends to discuss with other federal and state-level ministries whether a new body must be established to cope with these coordination tasks, or whether the KLMN should be strengthened, as suggested by the *Wissenschaftsrat*.

2. Involvement of institutional research activities in the marine research programme

The research activities of institutions which are funded by various ministries are an integral part of the marine research programme. As a rule, the German Federal Government will not provide additional research funds (e.g. in the framework of project promotion) for areas in which institutions already receive basic funding. There may be exceptions to this rule when the Government feels that the basic funding provided in a particularly important research area is not sufficient. The share of basic research funding which the German Federal Government is expected to provide is largely covered by its basic funding of institutions. This funding is to complement the contribution to be made in this sector by Germany's federal states. Should it become necessary to step up basic research efforts because of particular requirements, funding can be provided to a limited extent and for a limited period of time in the form of knock-on project financing.

Project funds can also be used specifically to initiate cooperation among institutions or with industry in priority research areas.

What is important in this context is that there must always be one specific institution which – because of its specific scientific orientation – is put in charge of the **coordination and monitoring of the overall project**. This facilitates a systematic hands-on approach while at the same time delegating more responsibility to scientists.

3. Using project promotion in order to step up efforts in important sub-sectors with the aim of establishing these activities in the long-term and other sponsors taking over the funding

The primary purpose of the Federal Government's project promotion funds is to encourage new activities and to foster interdisciplinary cooperation. Combining project activities and concentrating on priority areas are effective

means to help the federal states to **build up new research structures**. Systematic project promotion helps the universities in their **long-term planning and organic development** of necessary measures designed to restructure their research capacities, with the aim of subsequently pursuing these activities independently without any (major) contributions from the Federal Government. This also applies to non-university institutions.

4. Involvement in planning and designing international research projects, as well as in coordinating and implementing German contributions, and their support by means of project funds

Marine research is international by nature. Studies which are designed to produce fundamental findings about the ocean and its role in the climate are currently being conducted in the framework of several long-term international programmes in which Germany is substantially involved. The objectives of the major programmes such as **WOCE** (World Ocean Circulation Experiment), **JGOFS** (Joint Global Ocean Flux Study) and **ODP** (Ocean Drilling Program) were defined on the basis of an international consensus.

The German Federal Government is doing its best to coordinate activities at national level in order to ensure that the German contribution to these programmes becomes more visible than it has been in the past.

German scientists are currently not yet as much involved in programmes funded by the EC (e.g. MAST Marine Science and Technology, see III.4 and Annex) as the Federal Government would wish. For this reason, the Government will endeavour to increase the German contribution by providing better information, offering incentives in the form of supporting measures and increasing the involvement of German scientists in programme discussions.

Third-World countries are indispensable and desirable partners in efforts aimed at globally analysing and assessing the entire ocean-climate-environment complex in keeping with its importance. For this reason, a transfer of know-how (e.g. by means of IOC, START) is in Germany's interest. In this context, cooperation at regional level should be promoted, e.g. with the Indian Ocean Marine Affairs Cooperation (IOMAC). In addition, one of the objectives specified in Agenda 21 (Rio Declaration) is to ensure sustainable development for the tropical coastal regions which are increasingly being strained by growing population pressure and competing uses of resources. The Government of the Federal Republic of Germany feels that there is also scope for cooperation in the field of marine research, e.g. by providing training.

5. Accelerating the transfer and the adaptation of modern, non-marine methods for up-to-date marine research

Marine research **depends on** the use of **modern methods**; for this reason, yet greater use should be made of know-how available from other fields of technology.

An increasing integration of available non-marine technologies in cooperative marine research projects can lead to **higher research quality**, set off a **transfer of human resources** towards marine research and help to **increase the utilisation and the scope** of existing capacities.

The BMBF is an "interface" for many modern technologies and can **initiate interdisciplinary cooperation in the field of technology development** by providing a platform for discussions. The purpose of such a multidisciplinary exchange of views is to enable marine scientists to discuss their problems with potential partners from other scientific disciplines such as biotechnology, materials research and information technology. Concrete possibilities are seen in the following fields: improving methods of sample analysis by using genetic markers; developing biosensors which are resistant to seawater; and automating the assimilation of data in order to generate prediction models in real time.

Future marine research will receive a strong impetus from the use of remote sensing by means of satellites. There is still a considerable need for research to make full use of the potential opportunities offered by this technology.

6. Developing an efficient infrastructure at national and international level

Interconnecting, optimising and expanding already established national **data base systems** and connecting them to international data bases will be a key task for the German Federal Government – also in the field of marine research. The purpose of this action is to improve the **exchange of information**, to develop comparative models, and – most importantly – to avoid redundancy in the planning and promotion of research.

Since German research vessel missions are planned a long time ahead, there is currently little **flexibility to respond to suddenly emerging requirements** (e.g. assessing the effects of large-scale pollution such as in the Persian Gulf). Efforts are being made in this context to improve international coordination of the use of efficient large-scale equipment (research vessels, satellites, etc.) in order not only to achieve better overall utilisation of the capacities available but also to improve cooperation in research on issues of overriding general interest. It would be useful in this context to have an international system of free research vessel capacity reporting.

7. Translating scientific findings into political action

A consistent improvement of international agreements on the protection of the marine environment – i.e. the Helsinki Convention (Baltic Sea) and the Oslo/Paris Convention (north-east Atlantic Ocean), and decisions of the International North Sea Conference – will require even greater efforts than in the past with regard to **systematically defining and supporting projects**, as well as comprehensively **evaluating** and using research findings obtained by promotion in the past, as a basis for political decision-making. Available findings are not yet used to the extent required. This applies in particular to the development of concepts and environmental technologies complying with the "state of the art" and "best environmental practice" (now binding under the agreements mentioned above); and it also applies to improving the quality of environmental monitoring data (quality assurance of sampling and sample analysis) and to systematically evaluating research and monitoring results in the framework of expert reports and regular quality status reports.

The German Federal Government will continue to improve its dialogue with future users of research findings in order to ensure that the latter's requirements will be taken into account early on during the development of research projects. Furthermore, the Federal Government is convinced that extensive critical evaluations of research findings carried out at regular intervals can make a major contribution towards improving the foundations for environmental policy actions. For this reason, the Federal Government intends to create the necessary conditions to this effect when it drafts the amended version of the **Bund/Länder-Messprogramm (BLMP – Joint Monitoring Programme of the German Federal Government and Germany's Federal States)** for the North Sea and the Baltic Sea.

There seems to be a need to achieve direct and more active involvement in the planning of international monitoring projects such as GOOS (Global Ocean Observing System).

III.3.2 Scientific Programme

III.3.2.1 Basic Marine Research

As one of the highly developed civilised and industrialised nations in the world, Germany cannot escape its responsibility for the global environment, nor does it want to do so. Germany has played a key role in drafting some of the international agreements in this field, and it has undertaken to adopt preventive measures designed to protect the environment, and hence, to preserve the resources which are vital for humanity's survival. However, taking preventive action requires exact

knowledge of the processes on which global change is based and by which it is controlled. There still is considerable need for basic research in this regard.

The German Federal Government promotes basic marine research projects in areas in which there is **still a considerable lack of knowledge with regard to the solution of problem-related and application-oriented issues**. In this context, the German Federal Government concentrates its promotion on areas in which scientists consider that there is an urgent need for research, as described by and large in Chapter II.2. Unlike the DFG, however, which covers the full spectrum of basic research, the Federal Government's efforts are focused on selected priority areas.

World Climate Research Programme (WCRP)

Joint initiative by ICSU and WMO. Objective: to obtain quantitative data on the climate and to improve global and regional climate predictions over various time scales.

Core projects (examples):

WOCE (World Ocean Circulation Experiment) is designed to provide extensive data on the entire ocean, to be used as a basis for developing realistic models of global circulation and meridional heat transport in the ocean.

TOGA (Tropical Ocean Global Atmosphere) is focused on the interactions between the ocean and the atmosphere at lower latitudes, and their effects on the global atmospheric circulation.

GEWEX (Global Energy and Water Cycle Experiment) is designed to study all the components of the global energy balance and the water cycle; see also BALTEX, which is a regional contribution to GEWEX.

International Geosphere-Biosphere Programme (IGBP)

The purpose of this programme is to obtain findings about the physical, chemical and biological processes and their interactions which regulate the entire system of the Earth. In addition, the programme is designed to analyse the natural and man-made changes in this system.

Core projects (examples):

The purpose of **JGOFS (Joint Global Ocean Flux Study)** is to understand the global processes which control the carbon balance of the ocean, as well as the exchange between the ocean and the atmosphere, and between the ocean floor and the coast lines.

PAGES (Past Global Changes) is designed to find out about the major changes which occurred in the climate and in the environment in the past, as well as their causes.

Basic funding of institutions

Basic funding of institutions already covers a sufficiently broad spectrum of fundamental research issues.

The **Institut für Meereskunde in Kiel** (IfM – Institute for Oceanography) plays a key role in basic marine research. Its physical research projects are focused on large-scale ocean circulation, as well as the ocean's atmospheric forcing. For this purpose, the Kiel institute combines field monitoring in the North and South Atlantic Ocean and in the Indian Ocean with model calculations and the analysis of satellite data. Furthermore, the institute conducts process studies on a smaller scale. Theoretical oceanography deals primarily with vortex-resolving models of the North Atlantic Ocean and endeavours to explain their role. The biological/chemical studies of the IfM are aimed at analysing the structure and function of ecosystems, as well as their components, in various climate zones of coastal and open sea regions. A major objective in this context is to analyse the carbon cycle, with particular emphasis being placed on flows of substances at the water/atmosphere boundary (CO₂, organic matter) and their vertical transport in various climate zones (trace elements, organic marker compounds).

The **Institut für Ostseeforschung an der Universität Rostock in Warnemünde** (IOW – Rostock University Institute of Baltic Sea Research in Warnemünde) is involved in broadly based interdisciplinary research of the Baltic Sea. Its efforts in the field of physical oceanography are focused on monitoring and modelling water circulation and the transformation of water masses in the Baltic Sea. The institute's main fields of activity include the analysis of water exchange processes between the Skagerrak and the Baltic Sea, as well as the mesoscale water dynamics due to wind and pressure gradients, and due to topography and coastal morphology.

In the field of marine chemistry, the institute's research is focused on the mass balances and the biogeochemical cycles of substances. In biological oceanography, the institute deals with the substance flows between pelagic and benthic systems, and with ecophysiological phenomena in the Baltic Sea and in its coastal zones.

Research activities in the field of marine geology centre on the development of an integrated geological model of the Baltic Basin, as well as its dynamics, the development of its sediments and the interactions within the ecosystem.

Based on a management agreement with the BSH, the IOW is in charge of Baltic Sea monitoring.

WATIS – the Wadden Sea information system of **GKKS** – and the associated R&D programmes provide important basic ecological data on the North Sea coast lines. Input/output analyses of the estuarine region have provided the first reliable

estimates of actual inputs of substances from the river Elbe to the North Sea. The institute's activities in the field of climate research are expected to provide data on atmospheric inputs of water and substances to the North Sea.

The **Biologische Anstalt Helgoland** (BAH – Helgoland Biological Institute) has made major contributions to basic research in the field of **marine biology**. In addition to conducting long-term studies on the dynamics of biological processes in the North Sea, the institute is also highly interested in questions relating to the structural and functional adaptation of marine organisms to their habitats.

Through their participation in the **Taxonomische Arbeitsgruppe** (TAG – Taxonomy Working Group), the **BAH** and the **Forschungsinstitut Senckenberg** (FIS – Senckenberg Research Institute) – in cooperation with the AWI, the *Bundesforschungsanstalt für Fischerei*, the University of Hamburg and the IfM Kiel – provide the taxonomical processing for a number of groups of organisms of biological expedition material from German research vessels. The TAG thus makes a fundamental contribution towards the assessment of both polluted and non-polluted ecosystems. This prepares the ground for future comparisons in changing habitats.

Project promotion

Major global issues of oceanography and climatology are currently being studied in the framework of large-scale projects: the **World Climate Research Programme** (WCRP), the **International Geosphere-Biosphere Programme** (IGBP) (see table) and the **Ocean Drilling Programme** (ODP). Through the promotion of corresponding projects, the German Federal Government will continue to enable German institutions to participate in these international programmes.

In certain cases, the German Federal Government will in future provide additional national research funds in order to support basic research efforts in oceanography and climatology which are funded through programmes of the European Communities (e.g. MAST; see III.4 and Annex). The purpose of this additional funding is to establish close links between national and European activities in terms of their substance.

New basic research priority

In the framework of the present programme, the German Federal Government will promote not only the international activities mentioned above but also the development of a new basic research priority: **deep sea research**.

More than 75 percent of the surface area of the world's oceans (53 percent of the Earth's total surface area) cover regions with depths of more than 3,000 meters.

The deep sea plays an important role in the global climate and ecosystem because it determines changes on a time scale of up to 1,000 years. The ocean floor sediments are the "memory" of changes on a much larger time scale.

Pilot project

A pilot project entitled **Flows of Substances and Energy in the Deep Sea** (quantification, modelling and forecasting) will be devised to close current gaps in our knowledge – taking into consideration the findings available to date and integrated in an international framework – in order to arrive at a comprehensive understanding of the system. This project will concentrate on studying the following questions: *deep sea circulation*; its role in the *carbon cycle*; the *structure and functions of the biotic and abiotic compartments* of the deep sea; and *palaeo-oceanographic studies* as a basis for predicting and modelling future changes in a coupled ocean/atmosphere system.

In order to carry out this research, it will at the same time be necessary to develop *innovative equipment and process technology*. The project will provide urgently needed basic data for *technology assessment* studies to be conducted on a broader scale (see III.3.2.2.4).

For this reason, the role of the ocean in the global climate system can only be understood if the deep sea is included. Unless we improve our knowledge of the functions of the deep sea, it will not be possible to describe the marine and global environment. It is due to the sheer size of the deep sea and the difficulty involved in gaining access to it for observations that we still fail to understand many deep sea processes and their relevance.

Our current knowledge of deep sea circulation (motion and propagation patterns of oceanic cold water masses) enables us to make a qualitative description, while a quantitative description is possible to a limited extent only. Currently available quantitative data on the role played by subsurface circulation in the climate system, and on biogeochemical cycles, are still insufficient. The processes occurring in the deep sea at the interface between sediment and water are of key importance when it comes to the question of the carbon volumes for which the ocean is a sink or merely a "storage tank". Statements about potential changes in the deep sea ecosystem can only be made if multidisciplinary cooperation enables us to close some major gaps in our knowledge of the current condition of this ecosystem.

Shedding light on the deep sea is not only important for our understanding of global climate and environmental aspects, but it is also of direct practical relevance.

Again and again, proposals are made to the effect that the deep sea should be used as a final repository for various waste materials such as radioactive substances, pharmaceutical products, warfare agents, sewage sludge or carbon dioxide. In some cases, this has already been done without considering or explaining the potential effects. It is also still uncertain what effects large-scale exploitation of mineral resources might have on the deep sea. In this context, Germany also has an obligation to draw attention to potential effects in time (cf. III.3.2.2.4.).

A pilot project on "Flows of Substances and Energy in the Deep Sea" will be developed in order to shed as much light as possible on aspects relating to the deep sea.

Summary

Basic Research

In future, the German Federal Government will continue to use basic funding of institutions in order to support the objectives of long-term international programmes. Wherever it is useful and necessary, the Federal Government will add to, or complement, its basic funding by making available project promotion funds. In addition, the Federal Government will also provide project promotion funds for certain basic research priorities such as deep sea research.

III.3.2.2 Problem-Related and Application-Oriented Research

III.3.2.2.1 Research into the Effects of Climate Change on Marine and Coastal Areas

Problem description

Globally speaking, the sea level has risen by about 15 centimeters in the past 100 years. There is evidence suggesting that the sea level will continue to rise in the next 100 years with increasing warming of the atmosphere. Among the various factors involved in this phenomenon, two certainly play a particularly important role: the melting of mountain glaciers and the thermal expansion of water. The effects of other factors, on the other hand, will tend to be limited to specific regions. In certain regions, the sea level may even fall instead of rise in relative terms as a result of these regional effects. For this reason, it seems preferable to talk about a changing sea level in future.

In the long term, the change in sea level will affect the open sea and, more importantly, the coastal regions. Increasing tidal ranges and more frequent storm-surge

water levels, for instance, can be expected to lead to more water flooding of intertidal regions and to increase water mass or sediment transport. In this context, research findings could become relevant for the design of coastal structures. It is not yet possible today to predict what impact this will have on the biocenoses found in these regions. Studies which have already been conducted suggest that there are biological switching mechanisms in these regions whose responses to oceanic and climate changes are very abrupt, complex and non-linear, including the mass extinction of entire populations. If the size of the intertidal areas which dry up during low tide decreases, for instance, this may have adverse effects on Arctic bird populations. This also applies to climate-induced changes in offshore waters or in the open sea. Adverse effects on the biocenoses found in these regions will ultimately also have an impact on fishing.

Tropical and subtropical coastal regions will be much more affected by such changes than the German coast lines. This will greatly jeopardise the sustainable development of these regions for their population. The *Wissenschaftliche Beirat für Globale Umweltveränderungen* (Scientific Advisory Board on Global Environmental Change) drew attention to this fact in its first report, which was submitted to the German Federal Government in June 1993.

Global environmental changes are not limited to climate change and its direct effects. They also include the effects which growing population and migration pressure have on coastal regions (in particular in the Third World). These interdependencies were explicitly mentioned at the Rio Conference on Environment and Development and in Agenda 21.

Research needs

Our ability to assess the relative threat to oceanic and coastal regions and their habitats primarily depends on our knowledge of the conditions currently prevailing there. Such fundamental information is expected from the research projects described in III.3.2.1 for the oceans and in III.3.2.2.2 for regional waters, as well as corresponding research projects in the tropical and subtropical regions. The findings of these research efforts will lead to the development of models for the hydrodynamics, substance cycles and the energy balance, as well as the dynamics of the living organisms. These models, in turn, will provide the basis for scenarios which should help to predict future developments.

It will be necessary to collect data continuously and worldwide if we want to be able to make reliable predictions with regard to long-term changes in the oceans and variations in the climate. The IOC has already given some thought to the idea of establishing a *Global Ocean Observing System* (GOOS). Germany will make contributions to such a system. Although determining the overall scope required

for such a monitoring network will only be possible after a critical evaluation of the international programmes currently under way (e.g. TOGA, WOCE, JGOFS), a basic programme should be developed as soon as possible.

As far as oceanic conditions are concerned, there seems to be a need for improving our estimates of the ocean's capacity to absorb man-made carbon dioxide and for analysing potential climate-induced variations in hydrodynamic parameters. Major changes in ocean circulation could also have a substantial impact on regional precipitation patterns as well as the salinity and circulation of coastal waters. In this context, research efforts should be focused on the effects on coastal and offshore areas and the repercussions on the biocenoses in these areas, as well as on specific animal and plant species.

Basic funding of institutions

In the framework of the German Federal Government's basic funding of institutions, all marine research institutions will be able to make contributions to climate impact research in their specific fields of responsibility in basic research. Because of the locations of its Wadden Sea station in List on the island of Sylt and of its ocean station on the island of Helgoland, the *Biologische Anstalt Helgoland* (Helgoland Biological Institute), for instance, is particularly well placed to conduct long-term studies in the coastal region and the southern part of the North Sea. The same applies to the *Institut für Ostseeforschung* (Institute for Baltic Sea Research) with regard to the Baltic Sea.

In future, the *Kuratorium für Forschung im Küsteningenieurwesen* (KFKE – Foundation for Coastal Engineering Research) will primarily deal with interactions between the ocean and coastal structures. Efforts will be focused on conducting studies designed to optimise interventions in natural processes in coastal regions. In this context, particular attention will be paid to sand fills and wide-area coastal protection.

The *Potsdam-Institut für Klimafolgenforschung* (PIK – Potsdam Institute for Climate Impact Research), which is currently being established, will play a key role in the processing and assessment of primary data collected at various locations.

Project promotion

One of the priority research areas will be entitled "Climate Change and the Coast". Based on the institutional research capacities available, the objective will be to develop a collaborative project which will effectively combine relevant research activities carried out in this field at national level.

Summary

Research into the Effects of Climate Change on Marine and Coastal Areas

The German Federal Government will make national contributions to support international research programmes designed to study the global long-term change caused by natural and human-induced factors in the interactions between the ocean and the atmosphere, including the regions of the Third World. The German Government will participate in the development of a Global Ocean Observing System (GOOS).

In addition, the German Federal Government will fund a collaborative project entitled "Climate Change and the Coast", bearing in mind available institutional research capacities. The purpose of this priority research into specific regional issues in the North Sea and Baltic Sea regions is to identify potential future effects of climate change.

III.3.2.2.2 Regional Priorities in Marine Environmental Research

Problem description

The natural conditions prevailing in epicontinental seas such as the North Sea and the Baltic Sea are quite different from those in open oceans. Their ecosystems are largely controlled by specifically regional fresh and salt water circulation and mixing processes. In addition, they are subject to inputs of natural and man-made substances, in particular in near-shore areas.

The North Sea and the Wadden Sea. Like all shelf seas, the North Sea is an important mediator between the land and the ocean in the global cycles of impulse, energy and substances. For this reason, North Sea research must be oriented not only to (land-based) studies of the Wadden Sea and estuaries but also to (sea-based) studies of the ocean, in particular the Atlantic Ocean. North Sea research – like Baltic Sea research – is thus an important component of the "Global Change" programmes implemented worldwide (e.g. JGOFS, GEWEX, LOICZ).

Since the North Sea has historically been the object of the longest and most comprehensive scientific studies, major basic functions of this large marine ecosystem have already been identified. As a representative shelf sea, the North Sea is an excellent model for practising the integration of various lines of research to arrive at an overall system perspective.

For this purpose, it will be necessary to eliminate deficits in disciplines which have not yet synthesised their knowledge in the form of functional models so that they reach the standard achieved in those disciplines in which such models have

already been developed (e.g. physical oceanography and meteorology). System ecology is based on these disciplines.

The availability of long-term and large-scale biological monitoring data ("Helgoland Reede", CPR (Continuous Plankton Recorder) and ICES "Youngfish Surveys") on the North Sea, in combination with new synoptic monitoring methods (remote sensing from satellites), is a precondition for synthesising ecological knowledge in adequate simulation models. It will be necessary to include in these models not only controlling factors such as the climate, the Atlantic Ocean and terrestrial effects but also response patterns of key organisms and biocenoses (e.g. in the Wadden Sea), which ultimately determine the efficiency of the North Sea ecosystem.

Pilot project: North Sea

The KUSTOS pilot project (KUSTOS stands for *Küstennahe Stoff- und Energieflüsse – der Übergang Land-Meer in der südöstlichen Nordsee*, i.e. Near-Shore Flows of Substances and Energy: the Land/Sea Interface in the South-Eastern Region of the North Sea) was set up as a German contribution to the international IGBP programme entitled Land/Ocean Interaction in the Coastal Zone (LOICZ).

The purpose of KUSTOS is to study the flows of substances and energy in the offshore region between the land and the sea, which is a crucial interface in global cycles. The project will be focused on the southeastern region of the North Sea. Although data are available here both for the open sea (owing to the ZISCH and PRISMA projects) and in future also for the Wadden Sea areas (owing to the SWAP and ÖSF projects), nothing is known so far about the interactions between these maritime and terrestrial systems.

A systematic analysis of the water, substance and energy balances in the German Bight will be carried out in the framework of KUSTOS in order to close this gap, thus permitting an overall assessment of the North Sea ecosystem. The studies will be focused on the most important "global change" parameters (carbon, nutrients, N, P, Si), based on field experiments, satellite-based remote sensing and model calculations.

The coastal waters with their marine and estuarine regions differ considerably from the open North Sea because of their morphological diversity, their pronounced tidal effect, their mixed hydrographical zones, their high ecological substance conversion and transport rates, as well as their own population of organisms. The extensive transitional zones between terrestrial, limnetic and marine habitats are particular characteristics of coastal waters.

The importance of the estuaries and the Wadden Sea of the North Sea goes beyond regional bounds because these areas serve as nurseries for fish and crustaceans,

they are used by coastal birds for brooding, resting and as a source of food, and they are a habitat for seals. For human beings, the estuaries are preferred sites for transport and industrial plants, and the Wadden Sea with its islands is an important recreational area. Germany's coastal states have made the Wadden Sea a national park.

The Dutch, German and Danish tidal flats form one entity. For this reason, cooperating and exchanging information with Dutch and Danish working groups is an important prerequisite for effective research. The Common Secretariat of all Wadden Sea countries has assumed the task of coordinating all research efforts aimed at protecting the Wadden Sea.

The Baltic Sea and its Boddens. The Baltic Sea is the Earth's biggest brackish water sea. It is a largely closed ecosystem which is particularly suitable for studying not only natural processes but also the effects of human activities on large water bodies and their biota.

The exchange of water with the North Sea is limited to the two belts and the sound. This leads to long water renewal periods (about 30 years). In addition, the pronounced stratification of the Baltic Sea hampers the vertical exchange of water so that the Baltic Sea is exposed to a particularly high risk of accumulation of contaminants. The stagnating conditions prevailing in the deep water of the Baltic Sea promote the development of oxygen deficiency and hydrogen sulphide; in addition, they have an adverse effect on the ecological condition of the Baltic Sea and on its biogeochemical substance flows.

The Boddens and lagoons of the German Baltic Sea coast are inner coastal waters which are unique types of landscape found only in the Baltic Sea. These tideless, shallow brackish-water biotopes are "filtering and buffering systems" for the Baltic Sea which, when fully functioning, reduce the pollution load of the open sea caused by terrestrial inputs. Since their hinterland is a preferred site for settlements, they are also important economic regions, in which claims for diverse uses by industry, agriculture, fishing and tourism compete with the requirements of environmental protection.

Embedded in this landscape, the Boddens and lagoons are exposed to effects from the entire catchment area and from the open Baltic Sea. In the past few decades, inputs of nutrients and organic matter – mainly in the region of Mecklenburg/ Western Pommerania – have led to an overload, involving the risk that the Boddens and lagoons may lose their "filtering and buffering effects" for the Baltic Sea, and that, instead, they may increasingly develop into sources of intensive pollution. Because of the complex interactions involved, it will be more and more difficult to predict consequential processes.

Our current knowledge of the overall region varies widely. The studies conducted to date range from simple monitoring exercises to complex ecosystem analyses such as those carried out in the Darss-Zingster Bodden chain and the Kiel Bight.

The variability of individual processes is a characteristic feature of the Boddens and lagoons. Overall, they lead to a relatively high level of resilience of these ecosystems. Apparently, this stability is largely due to the following factors: the microbial food structure; its potential for short-term regulation; the ecophysiological adaptability of the higher organisms which in some cases is extremely developed; most importantly, however, the extraordinary regeneration potential of its populations.

Research needs and funding

Today's research has evolved above and beyond merely taking stock and describing specific parameters. Instead, it is focused on analysing deleterious effects on organisms and biocenoses. The interdisciplinary approach required for this purpose sees the epicontinental seas, as well as the estuaries, the Boddens and the lagoons as mediators between the ocean, the land and human beings. The conversion and transport balances of natural and man-made substances need to be quantified, and their qualitative properties need to be analysed. In this context, a distinction will have to be made between the spatial and temporal dependencies which are inherent in the system and those that are imposed upon the system by meteorological processes. Remote sensing methods can help to identify spatial structures and the directions of transport flows, and to extrapolate biotope-based processes.

Other important methods include field experiments aimed at analysing complex interactions and computer simulations used for three-dimensional modelling of transport and mixing processes.

Precise knowledge of the structure and the functioning of these ecosystems permits an assessment of the effects of current and future environmental policies. Furthermore, it is possible, based on such knowledge, to make well-founded assessments of the effects of envisaged measures in the fields of water management and hydraulic engineering.

The North Sea. North Sea research is aimed at developing, verifying and applying a complex model which contains quantitative and qualitative data on the causal interactions between atmospheric forcing, the hydrodynamics and thermodynamics of the water body, chemical conversions in the atmosphere, the water and the sediment, and the activity of organisms. For this purpose, the current research efforts (ZISCH, PRISMA) will be further pursued or optimised. In addition, there are complementary research projects (SWAP and ELAWATT) aimed at analysing the Wadden Sea ecosystem. These projects will also be continued. The financing of this research will include the basic funding provided to the BAH, the FIS and the GKSS.

The Baltic Sea. Because of the specific oceanographic conditions prevailing in the Baltic Sea (see above), there is an urgent need for a **comprehensive study of its ecological condition**. The purpose of this research will be – based on the extensive data collections available at the *Institut für Ostseeforschung* (Institute for Baltic Sea Research) as well as further experimental and theoretical studies on physical, chemical, biological and sedimentological issues – to develop models which describe the **condition of the Baltic Sea** and which provide information on **process interactions** between the sea bed, the water and the atmosphere.

The studies will be primarily designed to identify specific Baltic Sea problems, to analyse natural and man-made factors which perturb the ecosystem, and to shed light on their interactions in order to be able to estimate future developments. Furthermore, these studies are expected to provide the necessary information needed to define measures aimed at protecting and preserving the Baltic Sea as a habitat, even if the use of its resources increases.

Pilot project: Baltic Sea

BALTEX is an international experiment which is designed to provide an update of the water and energy balance of the Baltic Sea and its large catchment area, and to relate these data to global climate trends. In cooperation with the other Baltic Sea countries, the IFM Kiel, the GKSS, the IOW and other institutions will also conduct studies on the long-term and short-term variability (ranging from decades to millenia) of the water balance of the Baltic Sea. Hence, the Baltic Sea Experiment (BALTEX) is expected not only to provide basic information to help improve climate research but also to improve the possibilities of environmental monitoring.

These basic studies will also include projects in the framework of the Baltic Sea monitoring programme. These projects will be relevant to the political negotiations on national and international agreements for the protection of the marine environment. However, the mechanisms which control processes such as salt-water intrusion in the Baltic Sea also need to be clarified.

Furthermore, research is urgently needed to shed light on the stability and buffering mechanisms of the Boddens and the lagoons. Demonstrating the unexpectedly great importance of the flow of substances by means of the microbial food structure in highly eutrophic regions will require a completely new approach.

Because of the shallowness of the Boddens and the lagoons, great importance must be attached to the interactions between the pelagic and the benthic regions, and to the sorption and exchange processes in the transitional zones between water and land, as well as at the interface between sediment and water, and in the

transitional zone toward the Baltic Sea. While questions of control are currently being studied in the pelagic region, there is still a considerable need for structural and functional analyses in the other regions. Without more in-depth basic studies in these other fields, it will not be possible to make any scientifically founded predictions of the future development of these waters, nor will it be possible to manage them systematically and effectively.

There are three priority areas for ecological research in the Boddens and lagoons of the Baltic Sea:

- analysis of substance exchange processes in the transitional zones between the inner coastal waters, the hinterland and the open sea;
- geo-ecological processes in the littoral zone and in the hinterland directly bordering on the inner coastal waters;
- ecological responses of the inner coastal waters to natural and human-induced factors.

Summary

Regional Priorities in Marine Research

The German Federal Government will continue to pursue, and extend the scope of, its research into **North Sea ecosystems**, while paying close attention to, and complying with, recommendations made at international level (e.g. the Integrated North Sea Programme of the North Sea Task Force NSTF). The Federal Government's main objective in this field will be to establish links between hitherto separate research efforts in order to shed light on exchange processes between the Wadden Sea and the open North Sea, and between the Wadden Sea and estuarine regions.

Furthermore, the German Federal Government will take appropriate action to support projects which contribute towards a systematic study of the conditions in the Baltic Sea, with the aim of obtaining a comprehensive overall analysis. The Federal Government has entrusted the *Institut für Ostseeforschung* (Institute for Baltic Sea Research) in Rostock-Warnemünde with the task of coordinating national efforts aimed at developing a corresponding framework concept for Baltic Sea research, and international cooperation with the other Baltic Sea countries.

The interdisciplinary research approach needed to study the **Boddens and lagoons** of the Baltic Sea will be ensured by close cooperation, in particular among the universities of Greifswald and Rostock and the IOW. For this purpose, these three institutions will initiate a collaborative research project which will also involve other national and international working groups.

III.3.2.2.3 Research into, and Monitoring of, Marine Pollution

Problem description

Since the ocean is a habitat for many living organisms, it is subject to intensive utilisation by human beings. In the open ocean, in coastal and estuarine regions – like in inland fresh-water areas – this leads to conflicts between the use of resources (transport, settlement, recreation, fishing, "receiving streams" for waste water) and the need for water pollution control and nature conservation.

Monitoring the status of the marine environment and keeping track of its change enables us to assess the success of the protective measures initiated to date; in addition, it helps us to detect potential hazards for human health, it reveals potentially harmful effects on organisms and biocenoses, and helps identify hitherto unknown problem areas. Status observations (such as the North Sea Quality Status Report submitted by the North Sea Task Force (NSTF) on behalf of the International North Sea Conference) are carried out under the auspices of the Paris and Oslo Commissions and by the Helsinki Commission, which prepares similar reports for the Baltic Sea.

The **marine monitoring programme** includes the observation of short, medium and long-term changes in the physical, chemical and biological conditions of the various maritime regions in order to be able to detect temporal and regional trends. It is part of a series of long-term observations which are carried out in accordance with scientific standards and methods. (cf. III.3.2.2.1).

The monitoring of the North Sea and the Baltic Sea with regard to inputs of harmful substances has evolved from physical and chemical oceanography, and its scope has grown with the advent of methods which made it possible to monitor not only oxygen and nutrients but also chlorinated and petroleum-derived hydrocarbons, as well as heavy metals and radioactive materials, even when present only in traces. Different requirements for the various disciplines involved, the history of monitoring and seasonal variations (e.g. primary production is at a minimum during winter) led to the development of highly diverse sampling networks and frequencies. As time went by, there was an increasingly urgent need for monitoring biological effects and trends.

In terms of organisational arrangements, the responsibility for monitoring coastal waters lies with the federal states, while the Federal Government is responsible for monitoring the open sea; in 1980, the federal states and the Federal Government agreed to introduce a joint monitoring programme for the North Sea (entitled Bund-Länder-Meßprogramm, or BLMP) which also helps to comply with the German obligations under the international Joint Monitoring Programme (JMP) and the nutrient monitoring activities carried out on behalf of the Working Group on Nutrients (NUT) of the OSLO and PARIS commissions.

There are plans to introduce an overriding monitoring programme for the North Sea and the Baltic Sea which would cover not only coastal waters but also the open sea. This programme, which will replace the former BLMP, will merge all former national, international and state-level programmes, and it will integrate some of the necessary accompanying research projects in the monitoring efforts. The purpose of this exercise is to obtain a more comprehensive overview of the current status of the two seas.

Marine pollution is controlled by legislative measures which prohibit or restrict permitted discharges into the sea, as well as by monitoring and prosecuting offenders, and by taking immediate action to combat the consequences of accidents (oil spills). Government action in Germany in this field is mainly guided by the principle of prevention and the "polluter pays" principle.

The primary goal of water or marine pollution control is to achieve a continuous reduction of human inputs of pollutants and nutrients via rivers and via the atmosphere. In this context, it is the task of marine research to monitor the physical, chemical and biological status of the various marine regions, to distinguish between natural and human-induced factors, to identify the processes which control the distribution of the various substances in response to the action of natural forces, and to determine the causes of biological effects (such as fish disease and changes in biocenoses).

In the event of a naval accident, the German coastal regions – in particular the North Sea coast – are exposed to high risks, due to the high volume of shipping with a high percentage of ships carrying hazardous cargoes, difficult navigating conditions in the intertidal regions, and frequent bad weather conditions. Most hazardous cargoes are either petroleum or petrochemical products. In addition, there is the risk involved in the exploration, production and transport of oil through submarine pipelines. If larger amounts of oil are discharged into the marine ecosystem, this may lead to severe environmental damage, as demonstrated in recent years by accidents of tankers or drilling platforms in other oceanic regions ("Amoco Cadiz", "Exxon Valdez", "New Haven", EKOFISK, "Braer"). In the German Bight, a major oil spill would have particularly severe effects because the unique habitats in the Wadden Sea are extremely sensitive to oil pollution.

Past governmental action

For this reason, the German Federal Government has introduced a number of steps designed to improve the traffic situation in the German Bight (including the monitoring of maritime traffic and compulsory pilotage) in an effort to prevent maritime accidents. In addition, the German Federal Government and the coastal states have jointly taken steps to prevent tanker accidents and to combat oil pollution. This also includes the development of oil-spill combat strategies and a long-term

equipment procurement programme. It turned out that there were shortcomings with regard to the technical conditions for effectively combating oil spills in the various areas to be protected (open sea, shallow water, Wadden Sea/beach), and for the disposal of the recovered oil.

In cooperation with the federal ministries concerned – i.e. the Federal Ministry of Transport (BMV), the Federal Ministry of the Interior (BMI), the Federal Ministry of the Environment (BMU) – and the coastal states, the Federal Minister for Education, Science, Research and Technology (BMBF) has funded a number of R&D projects in the past few years designed to **combat marine pollution**. The projects, which have meanwhile been completed, have led to the development of the following technologies:

- booms which can be used to contain oil slicks in the open sea and in shallow water areas;
- independently operating oil-spill clean-up vessels (THOR, BOTTSSAND, IMPOSS), equipment which can be attached to other ships (WESTENSEE, oil carpets, oil suction devices), as well as a special amphibian vehicle for operation in the Wadden Sea;
- biological methods for combating oil spills in Wadden Sea and dike areas;
- mobile equipment for the disposal and treatment of sediments contaminated by oil.

The Federal Minister for Education, Science, Research and Technology has spent about DM 60 million for the promotion of these projects. The newly developed equipment was handed over to the authorities in charge of combating oil spills.

Microorganisms play a particular role in the degradation of oil in a marine environment. In studies extending over several years, the BAH examined the presence, the distribution, the activity and the multiplication of oil-degrading bacteria in the North Sea. These studies showed that artificially inoculating such bacteria will not accelerate oil degradation, since degradation is controlled exclusively by abiotic factors.

Furthermore, feasibility studies were conducted to find out whether it is possible to combat chemicals accidents in the open sea and whether available oil-spill combat technologies can be used for this purpose. Research contracts were awarded to institutions for the development of a clean-up vessel which can be effectively used in accidents involving contaminants other than oil, and for the development of a computer-aided maritime accident management system (REMUS, which stands for *Rechnergestütztes Maritimes Unfallmanagement System*) designed to optimise the effectiveness of control measures.

The development of a second-generation aircraft-based monitoring system (DO 228) which is carried out in the framework of a joint project of the Ministry of Transport (BMV), the Ministry of Defense (BMVg) and the Ministry for Education, Science, Research and Technology (BMBF) is in its final phase. The sensors developed for this purpose (laser fluorosensor, microwave radiometer) will permit early and reliable detection, sizing and classification of oil spills, chemicals leakages and other forms of contamination of the ocean surface.

In an effort to spur on the development of German **marine monitoring** activities, the following measures have been introduced in the past few years:

- Implementation or use of research programmes with the aim of increasing the scientific effectiveness and the economic efficiency of monitoring operations. The OPTINOM programme (*Optimierung des Nordsee Monitoring*, i.e. Optimisation of North Sea Monitoring) is designed for this purpose and interacts with other programmes such as TUVAS (*Transport, Umsatz und Variabilität von Schad- und Nährstoffen in der Deutschen Bucht*, i.e. Transport, Conversion and Variability of Pollutants and Nutrients in the German Bight), PRISMA (*Prozesse im Schadstoffkreislauf Meer – Atmosphäre: Ökosystem Deutsche Bucht*, i.e. Processes in the Ocean/Atmosphere Pollution Cycle: the Ecosystem of the German Bight), and EVA & MEDA (*Empirische Variabilitätsabschätzung und Methodik der Datenerhebung*, i.e. Empirical Variability Assessment and Data Collection Methodology).
- The Umweltbundesamt (Federal Environmental Protection Agency) has funded, or intends to fund, research projects in the following priority areas(*):
 - research into the Wadden Sea ecosystem
 - research into ways of protecting marine mammals (seals, whales)
 - identifying the distribution of large algae (such as fucus), and mussels along the German Baltic Sea coast with a view to man-made phenomena (e.g. eutrophication) in order to include these data in the BLMP (*);
 - collecting long-term fishing data with regard to the ecological effects of fishing activities, e.g. the processing and further evaluation of inshore fishing data collected over the past 10 or 20 years with regard to the by-catch of non-target species (*);
 - efforts aimed at determining trends with regard to nutrients and pollutants, as well as potential climate-induced effects in long-term series of benthos studies at the German North Sea coast (*);
 - R&D projects addressing the problem of the eutrophication of the North Sea and the Baltic Sea;

- research into the effects of pollutants on the parasitisation of marine organisms (*).
- For decades, the *Biologische Anstalt Helgoland* (BAH, Helgoland Biological Institute) has devoted a substantial part of its research capacity to collecting long-term data on organism populations in the southern region of the North Sea, monitoring their changes over space and time, and analysing the factors responsible for these changes. On the island of Helgoland and in List on the island of Sylt, conditions are particularly favourable for continuous monitoring of water salinity, temperatures and transparency, as well as light penetration, plant nutrients, counts of marine and oil-degrading bacteria, phytoplankton and zooplankton, as well as other variables. The BAH is involved in the optimisation of the joint monitoring programme of the Federal Government and the state governments by carrying out modern impact research and offering advice.

Research needs

There are still major gaps in our knowledge of substance transport and substance cycles – in particular with regard to potential pollutants and nutrients – in the marine environment. It is necessary to analyse the transport of nutrients and sediment in the coastal region in order to be able to quantify sediment and pollutant flows in this region with sufficient accuracy. Since the atmosphere is an important transport channel or source for certain pollutants, it is very important to measure the atmospheric concentrations of these substances and their deposition on the open sea.

Particular attention should be paid to studying the ecological effects which intensive farming has on the North Sea and Baltic Sea, in particular with regard to the nutrient situation and the occurrence of algal blooms.

In order to assess current ecological conditions, it is necessary to know the natural background concentrations of relevant substances. The analysis of sediment cores may make it possible to date the deposits of certain substances and organism residues. Paleogeographical reconstruction and historical sources can also help improve our understanding of past and current trends. Combined with the establishment of continuous monitoring programmes, this knowledge may help us detect long-term trends to provide guidance for (political) action.

In the past few years, there has been major progress with regard to the methods applied to analyse key pollutants, in particular certain organic compounds. These methods will be included in present and future monitoring programmes. Greater importance will be attached to assuring the quality of the environmental data collected in order to ensure the comparability of the data obtained in various regions by different laboratories.

There is still a lack of suitable methods for detecting biological and ecological effects of pollutants. In order to assess the importance of chemical environmental data, it is necessary to know the effects of each separate substance as well as their synergistic effects. For this reason, there is a need for biochemical and physiological studies at the level of cells, individuals, populations and ecosystems. Research work on the abiotic, chemical decomposition of organic pollutants due to photo-oxidation will have to be continued.

Summary

Research into, and Monitoring of, Marine Pollution

In the next few years, the German Federal Government will revise its monitoring strategy in the course of the review of the Joint Monitoring Programme of the Federal Government and Germany's various federal states. In addition, the Federal Government will extend the range of the analytical methods applied to include other important parameters, and it will ensure appropriate quality assurance. Furthermore, sampling and analytical methods will be partially automated wherever this is reasonable, and the scope of data collection methods will be extended to include remote sensing techniques. The range of biological monitoring methods will be extended to include modern methods of cellular and molecular biology.

III.3.2.2.4 Research into Mineral Resources/Deep Sea environmental protection

Problem description

The sea bed and its subsoil contain mineral resources and hydrocarbons which are generally expected to play an important role in the world's long-term supply of natural resources. The primary task of marine research on natural resources is to develop methods and criteria which permit a more realistic assessment of the potential of these resources, in particular those located in deep sea regions which have not been explored to this date for technical and economic reasons. The results will be used as a decision-making tool for a long-term resources policy.

Natural resources include manganese nodules which are found at depths of between 4,000 and over 5,000 meters in the Pacific and in the Indian Ocean and which occur in concentrations which will probably permit their economic exploitation. In the Red Sea, there are large volumes of ore sludge at a depth of 2,200 meters. As early as twelve years ago, it was shown that the exploitation of these resources is technically feasible. Other deep sea resources that have been discovered so far include iron manganese crusts on sea mountains in the Pacific Ocean,

sulfide ores in the fracture zones near the spreading ridges of the ocean crust especially in the Pacific, as well as concretions of phosphorite in various near-shore regions. In response to the fall of commodity prices in the Eighties, the interest of companies in exploring these resources has declined.

So far, only manganese nodules and ore sludges have been mined in the framework of pilot trials. Only in exceptional cases will it be possible to scale up the technologies employed to an economically attractive level. The same applies to the environmental load extrapolated from these tests. For this reason, it is necessary to develop mining strategies and techniques which operate on a scale that is economically viable, while at the same time taking due account of environmental protection interests.

Extracting mineral resources from the seabed will invariably be associated with adverse effects on the marine environment, as will the use of the deep sea for storing waste, including radioactive material. Hence, the German Federal Government is attentively observing developments following the dumping of radioactive waste by the former Soviet Union. The extent of possible damage can only be assessed on the basis of well-founded knowledge of the ecological conditions prevailing in the mining area concerned.

Research needs and funding

Despite the lack of a short and medium-term perspective regarding the use of marine resources, the geoscientific exploration of deposits should continue, concentrating particularly on the genesis and characterisation of these resources.

The last major hydrocarbon deposits are assumed to be located below the continental slope (200 – 4,000 meters of water depth) and along the continental base (at a depth of over 4,000 meters). In order to assess the hydrocarbon potential of these areas, it will be necessary to conduct systematic geophysical studies on the geological structure and the geological development of these regions, as well as studies on their geochemistry and isotope chemistry. Since there is still a considerable lack of basic knowledge about the genesis and migration of hydrocarbons in deep sea areas, the studies designed to develop reliable models for assessing the potential should be continued. It is also necessary to develop reliable and cost-effective equipment and methods.

The responsibility for this research rests mainly with the *Bundesanstalt für Geowissenschaften und Rohstoffe* (BGR -Federal Institute for Geosciences and Natural Resources).

The major environmental problems involved in the use of deep sea minerals stem from the mobilisation of enormous volumes of material during ore production, the transport of stirred-up material over long distances by ocean currents and the resulting perturbations in large areas of the marine habitats.

The environmental impact is difficult to assess, especially since the results of past deep sea research can be extrapolated to a limited extent only as to the effects of these mass transports. In order to be able to assess the risk involved in deep-sea mining, it will be necessary therefore to develop new research approaches. The time that will pass until marine resources can be exploited cost-effectively will give researchers an opportunity to produce results in time which will permit risk assessments and the drafting of legal provisions for environmental protection.

The studies to be conducted with regard to the natural condition of the ecosystem in prospective mining areas (cf. deep sea research, III.3.2.1) will first of all have to be focused on the following issues: sedimentology; geochemistry; organism populations on the bottom and in near-bottom water layers; currents above the deep sea floor; and corresponding studies for medium water depths, into which dredgings from mining vessels would be discharged.

Furthermore, it will be necessary to develop mathematical models which simulate the transport of turbidities above the deep sea floor and at medium water depths, and to conduct experimental studies on the effects of high particle concentrations on plankton.

Large-scale experiments designed to permit an extrapolation of the effects of deep sea floor mining (sedimentology, geochemistry, biological reactivation of the seabed) should be carried out.

Finally, there is a need for pilot projects for predicting the effects of deep-sea mining on the environment. The findings obtained in the course of such projects should help to develop environmentally sound methods and technologies for extracting marine resources and provide guidance to political bodies in charge of drafting legal provisions on environmental protection in the context of deep-sea mining.

Summary

Research into Mineral Resources/Deep Sea environmental protection

The German Federal Government continues to support research into deposits of natural resources and the development of suitable methods, especially through its funding of the *Bundesanstalt für Geowissenschaften und Rohstoffe* (Federal Institute of Geosciences and Natural Resources). With its basic funding of this institution, the Federal Government will finance the development of prospection and exploration methods and equipment.

The German Federal Government will provide particularly strong support to international approaches towards deep-sea environmental research carried out in the interest of a forward-looking technology assessment.

III.3.2.2.5 Research into, and Use of, Living Resources

a. Fisheries research

Large parts of the ocean are used intensively as a source of animal proteins and fats of high nutritional value. For the time being, only two-thirds of the catch is used directly for the production of human food. The research into ecological, technological and economic prerequisites for an optimum sustainable management of marine living resources will also help considerably to elucidate biological oceanographical processes.

The **Bundesanstalt für Fischerei** (BFAFi – Federal Agency for Fisheries) in Hamburg and Rostock is the central authority on this subject in Germany. Research projects focusing on more specific issues are also carried out by the **BAH** and the **IfM Kiel**.

Research needs

One perpetual subject of basic fishery-related biological research is the continuous monitoring of the stocks of finfish, shellfish and crabs which are the targets of marine fishing operations, as a basis for a sustainable management of our marine food resources, so as to help us maintain current production capacities.

Basic biological fishery research will increasingly have to address synecological questions in order to understand the interactions between target fish species and their animate and inanimate environment. Optimum use of living resources – in terms of production biology – cannot be based exclusively on findings about the biology of individual species. Instead, the functional aspects of ecosystems will also have to be taken into consideration in the long term in order to be able to use fishing grounds to their full biological production capacity by means of multi-species models. This scientific approach will have to include studies which focus on the recruiting process of fish populations, whose erratic course has not yet been sufficiently explained. It is only recently that it has become possible to tackle this problem more effectively by means of newly developed methods and hypothetical approaches.

In the framework of its membership to the Antarctic Treaty and the International Convention on the Conservation of Antarctic Marine Living Resources, Germany is conducting ecological fishery studies designed to estimate krill and fish resources and to assess the role of the various species in the ecosystem.

In all biological fishery studies which require knowledge of the entire marine environment, physical oceanography plays an increasingly important role since marine life processes are controlled by such phenomena as currents, advection, vertical mixing, upwelling and internal waves.

The findings of marine chemistry become more and more relevant for fishery-related biological research because it can no longer be ruled out that inputs of a

variety of biologically active man-made substances lead to ecological changes, especially in epicontinental seas.

Developments in the field of fishing technology must be aimed at reducing energy consumption while maintaining the same level of efficiency, and at providing better protection for non-target individuals and species. Both behavioural biologists and engineers will have to be involved in research efforts to this effect.

Great importance must be attached to research into the ecological effects of fishing (e.g. bottom trawling and shellfish dredging). In this context, some studies should also deal with the problem of the by-catch, which constitutes a waste of resources and an "undesirable" source of food for sea birds.

In order to improve fish production by means of maricultural methods, it will be necessary to conduct studies in the fields of physiology and ethology and, once again, engineering. As in all forms of intensive livestock breeding, there are conflicts with environmental protection interests. For this reason, it is necessary, on the one hand, to study more ecologically oriented maricultural methods; and on the other hand, there is a need for improving methods of cycling technology, with the intensive involvement of microbiology.

b. Biological resources

The world's oceans contain a countless number of living organisms which have an even greater variety of physicomatabolic properties and in some cases are extremely specialised. Studying such forms of life and the underlying biological and chemical mechanisms might help us solve medical and chemical as well as industrial and environmental problems.

Certain sponges, for instance, produce anti-inflammatory agents (e.g. Manolides, Scalaradiol). So-called macrolactins have been isolated from bottom bacteria; in laboratory experiments, these macrolactins have been shown to prevent the growth of skin and intestinal cancer cells. Substances and biochemical reaction chains of marine organisms could be used to overcome technical problems. Substances which protect marine animals from overgrowth by algae and other organisms, for instance, might be put to effective use in marine engineering. In combination with semiconductor systems, certain receptors can be used as biosensors for a variety of purposes (including marine monitoring).

In hot springs on the ocean floor, there are bacteria which can endure temperatures of up to 350°C in a hydrogen sulphide environment. Likewise, at the bottom of the deep sea, there are animals which can accumulate metals such as mercury, chromium or lead in quantities which are up to a hundred times higher than the concentrations that would normally be toxic.

Preserving this biological and genetic reservoir, and making moderate use of it in order not to jeopardise it, is also in line with the Convention on Biological Diversity adopted in the framework of the Rio Declaration.

Research needs

As a contribution to the BMBF's biotechnologically oriented research priority entitled "Molecular Research into Natural Resources", marine organisms will be analysed with regard to particularly interesting substances or reaction chains which might lend themselves to industrial utilisation. A corresponding framework concept is currently being developed.

Summary

Research into, and Use of, Living Resources

The German Federal Government promotes fisheries research, mainly in the framework of its basic funding to institutions such as the *Bundesforschungsanstalt für Fischerei* (BFA -Federal Research Centre for Fisheries), the *Biologische Anstalt Helgoland* (BAH – Helgoland Biological Institute) and the *Institut für Meeresforschung in Kiel* (IfM Kiel – Kiel Institute for Oceanography).

In addition, the Federal Government will promote research projects designed to identify new, economically interesting substances or metabolic pathways found in marine organisms.

III.3.2.2.6 Marine Research and Monitoring Equipment

Problem description

The successful implementation of marine research is highly dependent on the availability of reliable, modern equipment. This applies in particular to projects carried out in the deep sea (cf. III.3.2.1). The equipment requirements in this field can safely be compared with those in the field of space research. By and large, this is also true for the marine pollution monitoring activities described in III.3.2.2.3.

Major German contributions to the development of marine research equipment have so far been focused on three areas: echo-sounding and sediment echosonography; marine physical probes ("CTD"); and sediment water sampling. While some remarkable concepts have been developed for complex wire-guided monitoring systems – also at international level – only limited efforts have been made to develop submersibles and robot systems.

The specifications of marine research and monitoring equipment must be oriented towards future scientific issues and the need for an effective protection of the marine environment. For this reason, it is important for scientists and other potential users (e.g. governmental supervising authorities) to define the requirements for the specific applications envisaged in close cooperation with engineers and companies active in the field of equipment development, and to make a joint effort to implement these requirements.

In Germany, there are about 30 enterprises – most of them small or medium-sized – which are developing marine research and monitoring equipment and methods. Since the number of users of such equipment is very small in Germany, these companies must try to sell their products internationally as well. Against the background of the emerging common market in Europe and stiff competition from overseas, it seems advisable for Europe to pool its human research and development resources as well as its production equipment in order to build up a common competitive industry based on the principle of division of labour. Some steps have already been taken in this direction.

The EC's MAST programme, for instance, has led to joint efforts toward the development of basic technology (e.g. sensors and instruments for marine research), which will be a platform for future industrial-scale developments.

Furthermore, in response to a German proposal, the EUROMAR project was established in 1986 in the framework of the EUREKA initiative (see Annex for further details).

In the few years since its establishment, EUROMAR has evolved into a European marine research technology forum. EUROMAR helps companies and research institutions from Germany and elsewhere with little or no public funding to cooperate in concrete projects. EUROMAR's role in this context is to facilitate contacts, exchanges of experience and opening up new markets for the benefit of all the parties involved.

Research and development needs

The experience of the global research projects carried out in the framework of IGBP and WCRP and of long-term programmes such as GOOS has shown that there is a need for comparable and reliable data. An indispensable precondition for this is the availability of equivalent and internationally accepted standards with regard to the monitoring and analytical methods applied, since this is the only way to ensure that the data which are compiled in the data bases established for this purpose will be uniform and usable for future reference. Generally speaking, there will be an increasing need for remote sensing methods and for automatic sampling and data collection.

Currently there is considerable need for improvement of monitoring devices in terms of their long-term stability (e.g. corrosion) and energy supply. In addition, it is

necessary to develop devices which will permit reliable sampling of inorganic and organic trace substances and of volatile compounds, and which will allow accurate measurements of substance transport in the water column or at the bottom of the sea.

An area in which the current level of development is still completely inadequate is that of sensors which can be used for directly and selectively determining chemical components in the sea, thus permitting an analysis of their fine structures and their dynamic conversion processes.

Finally, there is a need for an inventory of robotics systems for monitoring, sampling and experimenting operations, in particular in the fields of ocean floor, bottom and deep sea research.

Summary

Marine Research and Monitoring Equipment

Through its basic funding of institutions, the German Federal Government will continue to promote the development of equipment for application in specific fields.

In addition, the Federal Government will continue to fund projects aimed at developing or improving marine research and monitoring methods and equipment – mainly in the framework of European cooperation (e.g. EURO-MAR, ECOPS) – while expecting industry to demonstrate corresponding commitment of its own.

Furthermore, the Federal Government will foster a more intensive dialogue between marine sciences and high-tech industries, with the aiming of improving the transfer of technology.

III.4. Funding by the European Community

In 1983, the Community began coordinating its activities in the fields of research and technological development by defining multi-annual framework programmes.

On 23 April 1990, the Council adopted the **Third Framework Programme**, extending over a period of five years and funded with a budget of 5.7 billion ECU (on 15 March 1993, the Council decided to increase this sum to 6.6 billion ECU). The programme is composed of 15 specific sub-programmes. Marine research projects are funded in the framework of a sub-programme entitled "**Marine Science and Technology (MAST II)**" (1991-1994); funds are also made available – although on a smaller scale and limited to research relevant to the climate issue – in the framework of the EC's environmental programme.

The MAST Programme

MAST-II is a direct follow-up to the MAST-I pilot programme (1989-1992). The general objective of the programme is to contribute to the creation of a scientific and technological basis for studying, using, managing and protecting the European coastal waters and regional sea areas of the Community's Member States, and to give the various ongoing research activities the necessary Community dimension. The specific objectives of MAST-II can be defined as follows:

- to contribute towards broadening our knowledge of the marine environment and its variability, with a view to improving its management and its protection, as well as the prediction of changes;
- to foster the development of new technologies for studying, protecting and using marine resources;
- to improve coordination and cooperation among national marine research and development programmes in Member States, and to increase the efficiency of these programmes by making more effective use of research institutions and by promoting the transfer of specialised know-how and knowledge;
- to establish the technical conditions for, and promote the development of, common rules, standards and proposals for directives;
- to facilitate the training and exchange of personnel;
- to support European involvement in international oceanographic programmes.

Through MAST-II, the EC provides funding for projects which deal with biological and physical oceanography, the marine geosciences, coastal sciences and coastal engineering, as well as technology development for marine applications. New research priorities were established by broadening the geographical scope of the programme (the North Atlantic Ocean and the subpolar seas were added) and by introducing a number of specific large-scale projects. Supporting activities such as the development of common standards and coordination activities round off the spectrum of MAST. The annex provides detailed information on the range of activities funded by MAST.

Applications for project funding filed with the EC Commission are first of all reviewed by international juries of experts. The final decisions are made by CAN-MAST, a consultative committee in which all Member States are represented. On behalf of the German Federal Ministry for Education, Science, Research and Technology, a group of KLMN advisors (the Conference of Leading Marine Research Scientists of Northern Germany) ensures optimum coordination with national activities in Germany (for further details about coordination with national activities, see III.3.2.1, Project Promotion).

German position

The scope for European cooperation in the field of marine research has been considerably improved by the MAST programme. In the next few years, it will be essential to consolidate this basis and to broaden it wherever this appears reasonable and necessary.

With regard to the development of the EC's fourth framework research programme (1994-1998), the German Federal Government outlined its position in the **German Memorandum on European Research Policy** as early as in spring 1992.

The German Government supplemented its memorandum in late 1992 as regards marine sciences by means of a paper which it had prepared in consultation with scientists. This paper, which was entitled "**German Views and Proposals for a MAST-III Programme**", was submitted to the EC Commission for consideration. The principal messages of this paper are as follows:

- Since the activities which were initiated under MAST I and II continue to be of topical interest and scientifically attractive, they should by and large be pursued under the EC's future marine research programme. The German Government feels, however, that the programme should be given a more distinct profile by **streamlining the activities that are eligible for funding and by focusing on priorities** which are particularly well suited for cooperation.
- From a German perspective, it is particularly important to **concentrate on man-made and climate-induced effects** on Europe's marginal seas and coastal regions. In this context, the German Government proposed, among other things, to carry out a **specific Baltic Sea programme** involving the participation of all Baltic Sea countries. EC funding for such a programme would be all the more useful since this programme would have an integrating effect in particular for the new Baltic states.
- Spending on **technology development** should not exceed 25 percent of the EC's budget for the marine sciences. From a German perspective, this would sufficiently meet the funding requirements for basic development work. Any additional technology development at European level should be conducted in the form of **cooperative projects under EUROMAR** (see Annex). The German Federal Government recommends to the EC Commission that it should cooperate with EUROMAR more closely than it has done in the past. This applies in particular to the development of equipment and infrastructure for large-scale European projects (ECOPS, see below).

Further research options at European level

In its recommendations for improving European cooperation in marine and polar research, the **ECOPS advisory group**, which was established by the EC Commission and the European Science Foundation (ESF), proposed several preliminary **research priorities**, referred to as "grand challenges". In addition to two polar research projects, ECOPS suggests that an operational system for monitoring the oceans and the European waters should be developed and implemented as a European contribution to GOOS. Furthermore, the group proposes that a large-scale project should be conducted to study the variability of the ocean floor. For the implementation of these proposals, the ECOPS advisory group recommends, among other things, that a network of European research institutions should be set up. The ECOPS proposals are currently being elaborated in more detail for a discussion at EC level; in fact, they may serve as a broader basis for the EC's fourth framework programme.

The German Federal Government explicitly welcomes the ECOPS initiative and will introduce **complementary measures at national level** which will lead to close links with the activities envisaged at European level. One such measure will be to increase the basic funding of deep-sea research (cf. III.3.2.1).

III.5 Financial Framework

(in DM millions; Source: German ministries)

	Estimated budgets					
	1992 actual	1993 target	1994 target	1995 target	1996 target	1997 target
1. BMBF ¹⁾	131.3	126.6	129.8	131.4	145.7	146.0
2. BMU ²⁾	9.4	6.0	4.4	1.2		
3. BML ³⁾	46.5	66.7	33.9	34.5	34.7	34.7
4. BMV ⁴⁾	24.1	25.9	29.6	28.0	28.2	28.2
5. BMWi ⁵⁾	0.5	0.6	0.7	0.7	0.7	0.7
6. BMVg ⁶⁾	20.4	23.0	22.0	22.0	22.0	22.0
Total	232.2	248.8	220.4	217.8	231.3	231.6

The budgeted figures are subject to the proviso that the financial planning can be adapted any time to the financial scope of the public authorities. As a general rule, the allocation of the funds mentioned above is subject to approval by the German Parliament.

1. Project and investment funds, as well as share of the Federal Government in the basic funding of the BAH, AWI, IOW, IFM, FIS
2. Currently earmarked amounts (R&D projects); budget estimates for 1996-97 are not yet available.
3. Expenditure of the *Bundesforschungsanstalt für Fischerei* (BFAFi) and funds allocated for research vessels (1992-93: including expenditure on construction of "Walther Herwig").
4. Share of research and development in total resources of the *Bundesamt für Seeschifffahrt und Hydrographie* (BSH; currently planned budget as of 9 August 1993) in accordance with 1991-92 programme budget (1992-97 = 20.74 percent). The R&D share includes the following items: personnel costs of research projects, infrastructure costs (DOD, experimental workshop, general administration), costs of materials for research projects, costs of ship use (including depreciation), costs for computer time.
5. Marine research expenditure of the *Bundesanstalt für Geowissenschaften und Rohstoffe* (BGR)
6. Basic funding of the *Forschungsanstalt für Wassershall- und Geophysik der Bundeswehr* in Kiel (FWG); including investments and expenditure on the WFS PLANET. The FWG has been entrusted, inter alia, with research on detection methods.

IV. Annex

1. *Information for Applicants* (applies to BMBF area only)

a. **Application procedure**

Applications for funding of research and development projects must be submitted to the *Projekträger Biologie, Energie, Ökologie* (BEO – Biology, Energy, and Ecology Project Management Agency), and not to the BMBF (Federal Ministry of Education, Science, Research and Technology). The BEO's office in charge is located in Rostock-Warnemünde (Projekträger BEO, Bereich Meeresforschung, Außenstelle Warnemünde, Postfach 30 1 28, 18112 Rostock).

All forms as well as the relevant guidelines and management principles can be obtained from the Warnemünde office.

Only projects which are oriented towards the objectives of the Marine Research Programme and which have not yet been started are eligible for funding.

Funds will preferably be allocated to interdisciplinary projects in which partners from various research disciplines pool their resources and choose a coordinator from amongst their own ranks in order to jointly find a solution to a given problem. Only in exceptional and well-reasoned cases are single-party projects eligible for funding.

Applicants should first of all present their projects to the management agency in the form of a short project outline (objectives, international R&D status, proposed solutions, time span and financial framework). In many cases, this outline enables the management agency to tell applicants what their chances are of receiving funding for their projects. In this way, applicants whose projects are not eligible can save themselves the effort of going through the application procedure.

Upon request and by appointment, the staff members of the project management agency will also be available to applicants for personal advice.

The following points will have to be taken into consideration when submitting an application (cf. application guidelines):

Project description (as concise as possible)

- summary:
- project objectives or R&D subject
presentation of project, description of problem, issues, scientific and technical objectives, what is to be implemented and how;

- relevance of the project to the promotion objectives of the Marine Research Programme;
- implementation and overall impact: what significance will the project's results have for what target groups, prospects of implementation and application in other fields, scope for direct implementation within the envisaged project (ways and types), significance of findings for further research;
- prospects for success as well as risks;
- the project's position in terms of the current status of science and technology (national and international);
- the applicant's previous work;
- description of work schedule or increments, as well as of alternatives.

Planning aids

Planning aids are designed to facilitate the processing and expert assessment of an application, i.e. they should be clear and easily comprehensible.

The following planning aids should be submitted:

- bar chart (schedule of work increments, possibly including reference to staff requirements);
- a structural plan or network plan for large-scale projects;
- a break-down of costs/expenses according to work increments/activities.

b. Project implementation

The project management agency will examine incoming applications to determine whether they are complete. The applications will then be assessed by experts and subjected to an administrative review. The final decision on whether, or not, funding will be made available will be taken by the BMBF, based on the complete application documents and the expert assessment.

Official notice of approval will be issued by the BMBF after an application has been approved.

Upon receipt of this notice, the research project can be initiated.

The project management agency will continue to be the contact point throughout the course of the project. All correspondence concerning the project – requests for payment, interim reports and progress reports, final reports and records of expenses – have to be submitted to the project management agency.

2. *EUROMAR: Organisation and Projects*

EUROMAR is a joint initiative of the BMBF and a team of European experts in marine sciences and technology who developed ideas on a project incorporating marine technology and environmental protection as early as 1985 – the year in which EUREKA was established. This project was then announced in June 1986 at the third ministerial conference.

In keeping with the general objectives of the EUREKA initiative, the following title was chosen for EUROMAR:

Development, Application and Use of Europe's Advanced Marine Technology with Global Market Potential

EUROMAR is dedicated to the following principles:

- to promote technological progress for an integrated ecological management of the marine environment
- to intensify cooperation between industry and science in the development of marine instruments and methods
- to improve productivity and competitiveness of the European marine industry in the world market.

EUROMAR sees itself as an umbrella project for sub-projects whose products, systems and services can help to achieve an ecological management of the oceans and seas. A **EUROMAR** sub-project must meet the following requirements:

- the projects must be transnational
- the projects must involve new technologies
- the projects must be characterised by an innovative scientific element
- the projects must be carried out in cooperation with at least two partners from industry and/or with two research institutes with the aim of developing new products or services
- the projects must be applied in the field of protection of the marine environment or management of marine resources

The following countries and international organisations are members of **EUROMAR**:

Croatia (observer status), the Commission of the European Community, Denmark, Germany, Finland, France, Greece, Italy, the Netherlands, Norway, Spain, Sweden, Turkey, the United Kingdom.

Currently, 19 sub-projects (each with a EUREKA number of its own) are in progress, covering the following subjects:

Remote sensing; modelling; data systems; ground-based systems and mesocosmos; instruments and landers; atmospheric inputs (see below).

The overall integration and cooperation of the various **EUROMAR** activities, as well as the examination of new projects proposals and the coordination with other specialised programmes (e.g. MAST) is handled by the **EUROMAR Board**, on which all Member States are represented. The international EUROMAR Secretariat, headed by the **EUROMAR Secretary-General**, is currently located in Rostock-Warnemünde (see list of addresses), and is financed from BMBF funds. The secretariat is the primary contact point for national and international partners; it provides information on current and planned projects, and offers advice to prospective applicants.

The regularly scheduled **Working Group Meetings**, along with the **EUROMAR Technology Markets**, ensure an exchange of information between scientists and engineers; in addition, they provide a forum for transnational contacts for the future European Market, and facilitate the search for new partners for innovative products and services.

Projects in progress

EU 450	EUROMAR – ATMOMAR	<u>A</u> tmospheric Pollutant Deposition to the <u>M</u> arine Environment	D, E, NL, S
EU 408	EUROMAR – BIMS	<u>B</u> enthic Instrumentation and <u>M</u> onitoring System	I, D, N, NL, S, SF
EU 406	EUROMAR – CAMERA	High Resolution Acous- tic 3D Imaging System	NL, F, DK
EU 819	EUROMAR – CARIOCA	<u>C</u> arbon <u>D</u> ioxide Exchange Seawater-Air	F, GB
EU 344	EUROMAR – CHARISMA	<u>C</u> haracterisation of <u>S</u> suspended <u>M</u> atter	N, NL, DK
EU 372	EUROMAR – DISC	<u>D</u> irected <u>S</u> ensor <u>C</u> arrier	NL, N
EU 628	EUROMAR -ECHOSEA	High Resolution, High Acoustic, Power <u>E</u> cho- graphic System for Exploration of the <u>S</u> ea Bottom and Sediment Structure	DK, F, I

EU 493	EUROMAR – ELANI	<u>E</u> lectro- <u>A</u> nalytical <u>I</u> nstrumentation	D, DK, GB, NL, Croatia
EU 413	EUROMAR – MAROPT	<u>M</u> arine <u>O</u> ptical Record- ing System	D, F
EU 423	EUROMAR – MARSIS	<u>M</u> arine Remote Sensing <u>I</u> nformation <u>S</u> ystem	I, D, F
EU 417	EUROMAR – MERMAID	<u>M</u> arine <u>E</u> nvironmental <u>R</u> emote-controlled <u>M</u> easuring and <u>I</u> ntegrated <u>D</u> etection	D, F, N, CAN
EU 410	EUROMAR – MOSES	<u>M</u> obile <u>S</u> tation for <u>E</u> nvironmental <u>S</u> urveys	NL, N, F, SF
EU 429	EUROMAR – OPMOD	<u>O</u> perational <u>M</u> odelling of Regional Seas and Coastal Waters	D, F, E, N, P, S, SF
EU 729	EUROMAR – PROBIO	<u>P</u> rogrammable/Event controlled Large Volume Filtration System for Long-term <u>B</u> iological Sampling	D, F
EU 441	EUROMAR – SEAMOS	<u>S</u> ea Environmental <u>M</u> onitoring System	I, D, F, N, NL, SF
EU 494	EUROMAR – SEASTARS	System for Airborne Remote Sensing of the Air	D, F
EU 453	EUROMAR – SEAWATCH	Experimental Operational Marine Environmental Surveillance and Infor- mation System	N, D, F, S, NL, GB
EU 409	EUROMAR – SMURV	<u>S</u> WATH – <u>M</u> ultipurpose <u>R</u> esearch <u>V</u> essel	D, E, I, GB, GR
EU 495	EUROMAR – VISIMAR	<u>V</u> isualisation and <u>S</u> imulation of <u>M</u> arine Environmental Processes	D, CEC, E, F, GR, I, N, S, SF, NL

3. The MAST-II Programme of the EC

Priorities of MAST II:

Part I: Marine Sciences

Oceanography is focused on the study of marine processes and flows. Although problem-oriented research is also taken into consideration, priority is given to projects which deal with processes and their interactions, as well as temporal and spatial changes. The programme calls for a multi-disciplinary approach designed to improve our understanding of the marine systems and to supply data for mathematical models.

Part II: Science and Engineering of the Coastal Zones

The main objectives are to improve our understanding of the physical processes and morphodynamics found in coastal regions, and to develop modern application concepts in the fields of coastal engineering and management.

Part III: Marine Technology

The priority of this part of the programme is to develop new, and improve existing, instruments required for use in the marine sciences, and to promote innovative technologies which are needed for the further development of marine sciences and for associated future industrial developments.

Part IV: Supporting Activities

Supporting activities are measures which complement research activities, and which are aimed at a more efficient utilisation of research and training facilities, as well as a more effective use of data. Currently, the following supporting activities are envisaged:

1. a European network for oceanographic data and information
2. preparation of rules and standards for marine sciences and marine technology
3. coordination of modelling
4. coordination of research vessels and facilities
5. designing of large-scale facilities
6. advanced training
7. new methods of surveillance and mapping

Part V: Large-Scale Regional Projects

The Commission is coordinating at least two large-scale interdisciplinary projects which cover specific geographic regions. Two of these projects are currently in the launching phase: one in the Mediterranean Sea, and one in the North Atlantic Ocean.

For further information please contact:

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DG XII/E
200, rue de la Loi
B-1049 Brussels
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EC Coordinator
Projektträger Meeresforschung BEO-KFA
Seestr. 15
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Fax: +49-381 - 5 15 09

4. *International Cooperation Agreements* (relevant to marine research)

Country	Type of Agreement	Area of Cooperation
Argentina	framework agreement (31 March 1969)	marine and Antarctic research (supplementary agreement)
Australia	framework agreement (24 August 1976)	marine research
Brazil	framework agreement (9 June 1979)	oceanography, marine biology
Canada	framework agreement (16 April 1971)	oceanography, marine geology and geophysics, marine biology marine research technology
Chile	framework agreement (28 August 1970)	marine research
China	agreement (20 November 1979) specialised agreement (27 June 1986)	marine geology hydrocarbons marine research; marine technology
France	specialised agreement (26 April 1974)	manganese nodule research
India	specialised agreement (29 April 1986)	marine technology
Indonesia	agreement (20 March 1979)	marine research
Japan	framework agreement (8 October 1974)	marine research
Mexico	fishery agreement (16 August 1974)	scientific study of the fish stocks in the waters of the Mexican Pacific coast
Spain	framework agreement (23 April 1970)	marine research
Soviet Union	framework agreement (22 July 1986)	science and technology (now applied to successor states)
Yugoslavia	framework agreement (23 May 1971)	marine biology (now applied to successor states)

Name of vessel	Owner	Operator G.T.	Shipping company	Year of construction	Size	Crew	Scientists	Areas of operation	Operations planning agency	Financing (operating costs)
FS Polarstern	BMBF	AWI	Hapag-Lloyd	1982	10,970	36	65	polar regions	AWI Director + Advisory Board of Users	90% BMBF 10% Bremen
FS Meteor	BMBF	University of Hamburg	RF	1986	3,990	32	29	Atlantic Ocean, Indian Ocean	Senate Comm. Oz. DFG	30% BMBF 70% DFG
FS Sonne	Partenreederei	Partenreederei	RF	1991 (conversion)	2,607	30	25	Indian Ocean, Pacific Ocean, Atlantic Ocean	ad hoc expert committee	BMBF private user
FFS WALTHER HERWIG	BML	Bundesamt für Ernährung und Forstwirtschaft		1973	2,250	40	12	NW Atlantic Ocean North Sea, EC seas	Bundesforschungsanstalt für Fischerei	BML
WFS PLANET	BMVg	FWG	German Armed Forces	1966	1,917	38	20	North Sea, Norwegian Sea	FWG/BWB	BMBF
FS GAUSS	BMV	BSH	BSH	1980	1,600	20	12	North Sea and Baltic Sea	BSH committee	BMV
FS VALDIVIA	University of Hamburg	RF	RF	1961/70 conversion	1,343	20	16	North Sea and Baltic Sea Arctic Ocean, Mediterranean North Atlantic Ocean	missions committee	University of Hamburg
FS ALEXANDER v. HUMBOLDT	State of Mecklenburg- Western Pomerania	IOW	BMS	1966	1,270	15	12	Baltic Sea, North Sea Atlantic Ocean	directorate of institute	BMBF/ M-V
FS POSEIDON	State of Schleswig-Holstein	IFM Kiel	RF	1976	1,049	18	12	NW Atlantic Ocean Norwegian Sea	IFM scientific staff	BMBF/ S-H
FK HEINCKE 2)	BMBF	BAH	BAH	1990	1,000	10	12	North Sea	vessel missions group	BMBF/BAH
FK ALKOR	State of Schleswig-Holstein	IFM Kiel	RF	1990	999	10	12	North Sea and Baltic Sea	IFM scientific staff	BMBF/ S-H
VWFS WEGA	BMV	BSH	BSH	1990	970	16	7	North Sea and Baltic Sea	BSH committee	BMV
VWFS ATAIR	BMV	BSH	BSH	1987	950	16	7	North Sea and Baltic Sea	BSH committee	BMV
FS VICTOR HENSEN	AWI	AWI	RF	1975	423	11	12	North Sea	V/HENSEN planning group	90% BMBF 10% Bremen
FFK SOLEA	BML	Bundesamt für Ernährung und Forstwirtschaft		1974	337	12	5	North Sea and Baltic Sea für Fischerei	Bundesforschungsanstalt	BML
FS PROFESSOR ALBRECHT PENCK	State of Mecklenburg- Western Pomerania	IOW	BMS	1953	306	10	12	Baltic Sea, Kattegat Stegerak	directorate of institute	BMBF M-V
FK UTHÖRN	BMBF	BAH	BAH	1982	254	5	25	German Bay	vessel missions group	BMBF
FK LITTORINA	State of Schleswig-Holstein	University of Kiel IFM	IFM Kiel	1974	175	5	6	western Baltic Sea Kattegat	Kiel University committee IFM	BMBF/ S-H
FFK CLUPEA	BML	Bundesamt für Ernährung und Forstwirtschaft		1949	46	4	3	Baltic Sea	BFAFI	BML
FK SENCKENBERG	Senckenberg, FFM	Senckenberg Wilhelmshaven	Jade-Dienst	1976	165	5	12	North Sea, Baltic Sea	Senckenberg scientific staff	BMBF/ Hessen
TERRAMARE I	Terramare GmbH	Terramare GmbH	Jade-Dienst	1991 conversion	26x7x0.8m	-	6	Wadden Sea	Terramare research group	Lower Saxony

6. Addresses

A. Federal Ministries

AA

Federal Ministry for Foreign Affairs

Adenauerallee 99-103

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BMBF

Federal Ministry of Education, Science, Research and Technology

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fax: +49-228-59-3601

BMI

Federal Ministry of the Interior

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BMWi

Federal Ministry of Economics

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BML

Federal Ministry of Food, Agriculture and Forestry

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BMVg

Federal Ministry of Defence

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BMV

Federal Ministry of Transport
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BMU

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
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BMZ

Federal Ministry for Economic Cooperation
Friedrich-Ebert-Allee 114-116
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B. State-Level Ministries

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Bremen

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MPG

Max-Planck-Gesellschaft Generalverwaltung
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FHG

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fax: +49-4421-42313

FTZ Forschungs- und Technologiezentrum Westküste

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D. Federal Institutes

BAH

Biologische Anstalt Helgoland

Zentrale Hamburg

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fax: +49-40-89693-115

Meeresstation Helgoland

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Wattenmeerstation

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BGR

Bundesanstalt für Geowissenschaften und Rohstoffe

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Labor Sülldorf

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BfG Bundesanstalt für Gewässerkunde

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FWG

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UBA

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E. Large-Scale Research Institutions

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GKSS

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F. "BLUE LIST" Institutes; MPIs

Institut für Meereskunde

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Institut für Ostseeforschung

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7. *Abbreviations and Acronyms*

ADCP	Acoustic Doppler Current Profiler
AWI	Alfred-Wegener-Institut für Polar- und Meeresforschung (Alfred Wegener Institute for Polar and Marine Research)
BAH	Biologische Anstalt Helgoland (Helgoland Biological Institute)
BALTEX	Baltic Sea Experiment
BFA	Bundesforschungsanstalt für Fischerei (Federal Research Centre for Fisheries)
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources)
BLMP	Bund-Länder-Meßprogramm (Joint Monitoring Programme of the German Federal Government and Germany's Federal States)
BMBF	Bundesministerium für Bildung, Wissenschaft, Forschung und Technologie (Federal Ministry of Education, Science, Research and Technology)
BML	Bundesministerium für Ernährung, Landwirtschaft und Forsten (Federal Ministry of Food, Agriculture and Forestry)
BMU	Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (Federal Ministry of the Environment, Nature Conservation and Nuclear Safety)
BMV	Bundesministerium für Verkehr (Federal Ministry of Transport)
BMVg	Bundesministerium der Verteidigung (Federal Ministry of Defence)
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit (Federal Ministry for Economic Cooperation)
BSH	Bundesamt für Seeschifffahrt und Hydrographie (Federal Maritime and Hydrographic Agency; formerly DHI)
CIESM	Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée
CMG	Commission on Marine Geology (IUGS)
CPR	Continuous Plankton Recorder
DFG	Deutsche Forschungsgemeinschaft (German Research Foundation)
DKRZ	Deutsches Klimarechenzentrum (German Climate Computer Centre)

DOD	Deutsches Ozeanographisches Datenzentrum (German Oceanographic Data Centre)
DWD	Deutscher Wetterdienst (German Meteorological Service)
ECOPS	European Committee on Ocean and Polar Sciences
ERFEN	Estudio Regional del Fenomeno El Niño
EUROMAR	European Project on Marine Research and Technology
FAO	Food and Agriculture Organisation
FIS	Forschungsinstitut Senckenberg (Senckenberg Research Institute)
FK	Forschungskutter (research cutter)
FS	Forschungsschiff (research vessel)
FUB	Freie Universität Berlin (Berlin Free University)
FWG	Forschungsanstalt der Bundeswehr für Wasserschall und Geophysik (Federal Armed Forces Institute for Underwater Sound and Geophysical Research)
GEWEX	Global Energy and Water Cycle Experiment
GKSS	Forschungszentrum Geesthacht GmbH (Geesthacht Research Centre)
GOOS	Global Ocean Observing System
GTG	Geomar-Technologie GmbH
HELCOM	Helsinki Commission (for the protection of the marine environment in the Baltic Sea)
IABO	International Association of Biological Oceanography
IAMAP	International Association of Meteorology and Atmospheric Physics
IAPSO	International Association for the Physical Sciences of the Ocean
ICBM	Institut für Chemie und Biologie des Meeres, Oldenburg (Institute for Marine Chemistry and Biology)
ICES	International Council for the Exploration of the Sea
ICSU	International Council of Scientific Unions
IfM(K)	Institut für Meereskunde, Kiel (Kiel University Institute for Oceanography)
IGBP	International Geosphere-Biosphere Programme

IOC	Intergovernmental Oceanographic Commission (of UNESCO)
IOMAC	Indian Ocean Marine Affairs Cooperation
IOW	Institut für Ostseeforschung Warnemünde (Rostock University Institute for Baltic Sea Research)
IUGG	International Union of Geodesy and Geophysics
JGOFS	Joint Global Ocean Flux Study
JMP	Joint Monitoring Program
JOIDES	Joint Oceanographic Institutions for Deep Earth Sampling
KFKI	Kuratorium für Forschung im Küsteningenieurwesen (Foundation for Coastal Engineering Research)
KLMN	Konferenz leitender Meeresforscher Norddeutschlandes (Conference of Leading Marine Scientists of Northern Germany)
LOICZ	Land-Ocean Interaction in the Coastal Zone
MAROPT	Marine Optical Recording System
MAST	Marine Science and Technology (EC programme)
MPI	Max-Planck-Institut
MUDAB	Meeresumwelt-Datenbank (im DOD) (Marine Environment Data Base of the DOD)
NSTF	North Sea Task Force
ODP	Ocean Drilling Programme
OPTINOM	Optimierung des Nordsee-Monitoring (Optimisation of North Sea Monitoring)
ÖSF	Ökosystemforschung Niedersächsisches Wattenmeer (Ecosystem Research in the Wadden Sea of Lower Saxony)
PAGES	Past Global Changes
PIK	Potsdam Institut für Klimafolgenforschung (Potsdam Institute for Climate Impact Research)
PRISMA	Prozesse im Schadstoffkreislauf Meer-Atmosphäre: Ökosystem Deutsche Bucht (Processes in the Ocean/Atmosphere Pollutant Cycle: Ecosystem German Bight)
RF	Reedereigenschaft Forschungsschiffahrt GmbH
SCOR	Scientific Committee on Ocean Research (ICSU)

START	System for Analysis, Research and Training
STEP	Science and Technology for Environmental Protection
SWAP	Sylter Wattenmeer Austauschprozesse (Sylt Wadden Sea Exchange Processes)
TAG	Taxonomische Arbeitsgruppe (Taxonomy Working Group)
TOGA	Tropical Ocean-Global Atmosphere
TUVAS	Transport, Umsatz und Variabilität von Schad- und Nährstoffen in der Deutschen Bucht (Transport, Conversion and Variability of Pollutants and Nutrients in the German Bight)
UBA	Umweltbundesamt (German Environmental Protection Agency)
UN	United Nations
VWS	Versuchsanstalt für Wasserbau und Schiffbau (Berlin Model Basin)
WCRP	World Climate Research Programme
WFS	Wehrforschungsschiff (military research vessel)
WMO	World Meteorological Organisation
WOCE	World Ocean Circulation Experiment
ZISCH	Zirkulation und Schadstoffumsatz in der Nordsee (Circulation and Pollutant Cycles in the North Sea)
ZMAW	Zentrum für Marine und Atmosphärische Wissenschaften (Centre for Marine and Atmospheric Sciences)
ZMK	Zentrum für Meeres- und Klimaforschung (Centre for Marine and Climate Research)
ZMT	Zentrum für Marine Tropenökologie (Centre for Marine Tropical Ecology)

8. Glossary

abyssal region	The deep sea region.
accumulation	In this context refers to the accumulation of contaminants.
actuogeology	Deals with contemporary geological processes.
advection	Transport caused by currents.
aerosols	Very finely dispersed solid or liquid substances suspended in the air.
autotrophic organisms	Organisms which elaborate all the chemical constituents they require from inorganic substances.
bathymetry	The measurements of depths of water in the deep sea.
bathypelagic	Refers to organisms living in the deep sea.
benthic region	The habitat at the bottom of the sea.
benthos	The biocenosis at the bottom of the sea.
Bodden	Shallow waters between a mainland and promontories or off-shore islands.
brackish water	Freshwater mixed with saltwater from the sea.
chemoautotrophy	The ability of some microorganisms to nourish themselves <u>autotrophically</u> without photosynthesis.
chemolithotropic organisms	Organisms which recover energy by using inorganic substrates.
ciliates	Unicellular organisms with fine hair-like protrusions or cilia.
convection	Density-induced vertical transport.
cryosphere	Cold regions of the Earth.
dumping	Here: The dumping of wastes into the sea from ships and aircraft.
El Niño phenomenon	Sporadic warming of the surface waters along the western coast of South America

ENSO phenomenon	El Niño Southern Oscillation: Large-scale variations in mean atmospheric pressure especially over the Pacific region.
estuary	The mouth of a river.
euphotic zone	The upper layers of the ocean which are penetrated by daylight.
eutrophication	Overfertilisation of surface waters due to excessive nutrient input. Eutrophication causes increased plant growth, leading to oxygen depletion in both the water and the sediment due to the decomposition of dying organisms.
geoid	Terrestrial body; shape of the Earth.
geostrophic currents	Oceans currents caused and maintained predominately by the Earth's rotation.
ground-truth measurements	Parallel measurements of marine parameters carried out to calibrate remote sensors.
heterotrophic organisms	Organisms requiring organic matter from outside sources for metabolic synthesis (non-green plants and all animals; antonym: autotrophic).
hydrosphere	All terrestrial waters including ice and snow.
hydrothermal deposits	Mineral deposits in submarine hot springs due to the precipitation of metal salts contained in spring water.
littoral zone	Ecosystem of the coastal areas which come into contact with seawater.
lithosphere	The outer, rigid shell of the Earth.
mariculture	Intensive breeding of fish and other marine animals.
monitoring	Conducting measuring campaigns on a routine basis.
nanoflagellates	Marine organisms ranging between 2 and 20 μm in size.
nekton	Larger, actively swimming aquatic organisms such as fish.

pelagic zone	The environment of the open sea.
plankton	Floating organisms with insignificant locomotor powers living in the open sea.
polynya	An area of open water in pack ice.
prospectivity	Here: The expected mineral yield of a given mineral deposit.
proxy data	Data which are known to have fixed ratios to the target parameters which cannot be collected directly.
reflection seismology	Subsoil exploration using artificial earthquake waves; measurements of the reflected waves.
refraction seismology	Subsoil exploration using artificial earthquake waves; measurements of the refraction of the seismic waves in the subsoil.
sediment	Deposition on the floor of an ocean or sea.
seismology	The science of earthquakes.
subduction zone	The area where a continental plate moves under another plate and is destroyed in the process.

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